

CONTEST: WOULD ALIEN CONTACT CHANGE THE WORLD?

FINAL FRONTIER

The Magazine of Space Exploration

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CRUISIN' 150 MILES UP WITHOUT A NET

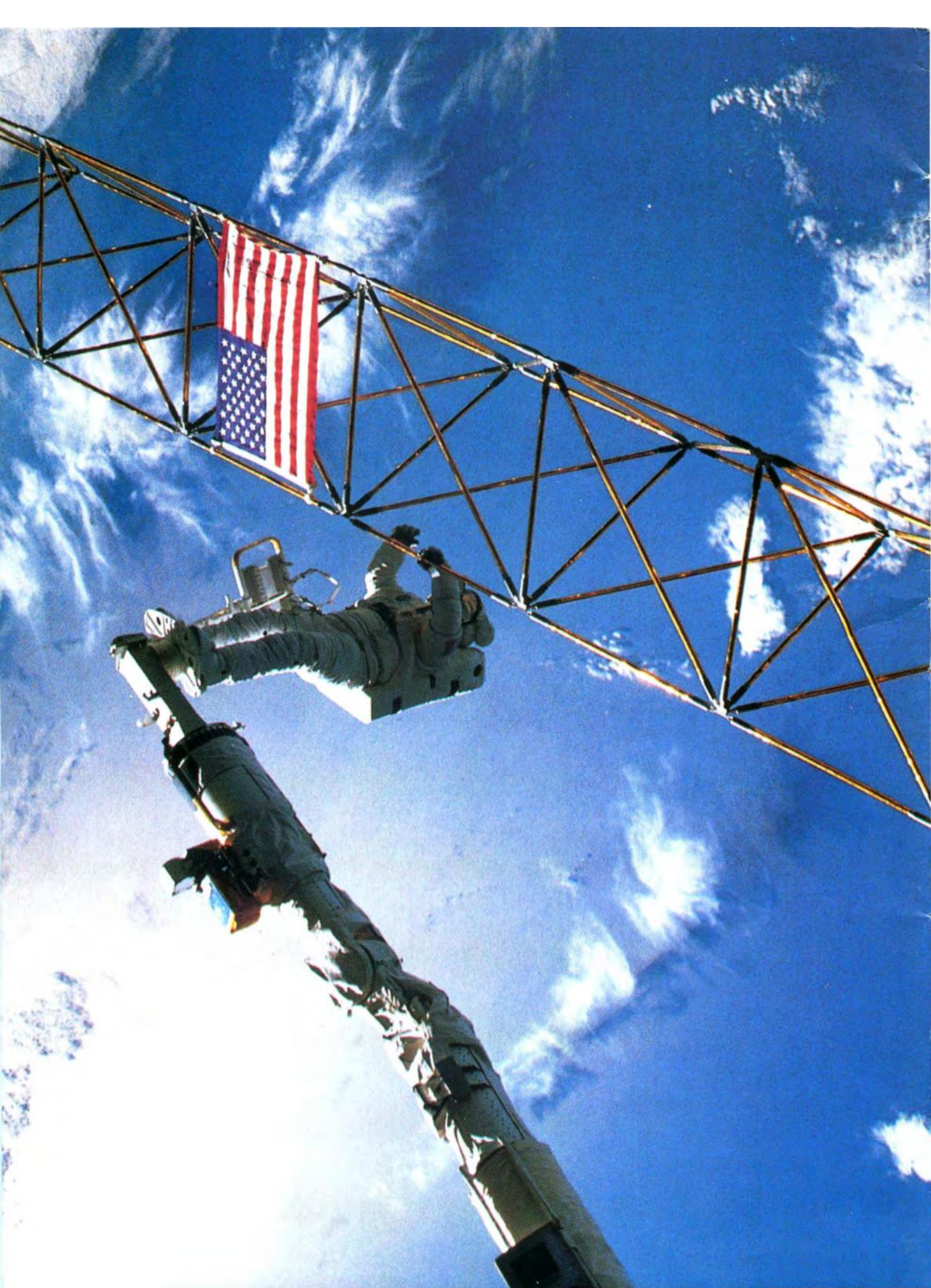
THE RED
PLANET:
SOVIETS HEAD
FOR MARS

WILLIE AND
SINATRA
PLAY AMONG
THE STARS

SPACE TOYOTA

MINI-POSTER:
ROCKETS
AROUND
THE WORLD







*How does it feel
to dangle your legs
above the Earth,
with your back
to the Universe?*

BY ALCESTIS R. OBERG

SOLO



The first thing you notice is the cold. Gliding away from the shuttle, a solitary human satellite orbiting the Earth, you feel an alien, absolute cold unlike any cold experienced by terrestrials.

"As soon as I got out of the payload bay," astronaut Bruce McCandless said, recalling his historic first flight of the "manned maneuvering unit" (MMU) backpack in 1984, "I was surprised at how very

chilly it got. I was shivering at times."

"I was freezing cold," said George "Pinky" Nelson, who used the rocket-powered backpack on the flight following McCandless' to rendezvous with the ailing Solar Max satellite. "The sun was at my back. I had the whole MMU between me and the sun, and the rest of me was pointed at deep space. So that was cold."

Former astronaut (now General) Robert Stewart, McCandless' crewmate on mission 41-B, remembered, "When I went out, I was very warm from working in the bay for quite some time. I could feel the difference, though. It's like laying in bed, being in the bay, where you're shielded on three sides from the cold. And when you leave the bay, it's like somebody pulled the cover off of you. You're not

necessarily cold right away, but you can feel the change in temperature."

Only five people in the world—all American astronauts—have experienced firsthand that alien frigid shock. All used the MMU backpack to fly, untethered, from as little as 50 to more than 300 feet from the shuttle, and all can lay claim to the title of "human satellite." (One other astronaut, James "Ox"



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Van Hoften, tested out the MMU within the confines of the shuttle bay on Nelson's Solar Max flight).

As is typical with NASA technical titles, the name "manned maneuvering unit" doesn't do justice to the reality. "It's like a three-dimensional magic carpet," said former astronaut Joe Allen, who rode the MMU during shuttle flight 51-A in 1984. "It doesn't make much noise when it moves, and it can move you in three dimensions." Astronauts in the MMU can somersault, pirouette, pitch, yaw or roll. They can move up, down, sideways, backward and forward, merely by moving their hand controls slightly. It's a freedom of movement only Superman could conceive of, free of muscle exertion and cardiovascular effort, free of wind and friction. "You use only your fingertips, your head and your eyeballs," said McCandless.

The "magic carpet," like all technical miracles, took over a decade to develop and test.

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The primary aim of the MMU was to provide astronauts with the ultimate mobility in space, movement that wasn't restricted to the near neighborhood of a spacecraft or limited

**It's a freedom
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muscle exertion
and cardiovascular
effort, free of wind
and friction.**



by the length of an umbilical cord. The primary anxiety, of course, was the horrible specter of the equipment failing and an astronaut being stranded in space. Early on, there was a

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plan to put the astronaut with the MMU on a long tether, and to reel him in if the backpack failed. But the engineers and astronauts convinced NASA management that the MMU could be tested before it ever left the payload bay. A long tether, they argued, would only complicate mobility and even endanger the astronaut by hampering his movement, wrapping around him or torquing in such a way as to smash him into the orbiter. They preferred to test the MMU for possible problems while it was still in the payload bay. If it did fail later, during a sortie, the orbiter could simply fly over and pick up the stranded astronaut.

"Astronauts must look like psychotics or lunatics proposing to fly around out there like that," said McCandless, who was heavily involved in designing the MMU before he flew it in space. "But we asked them to believe us, and they agreed to take the risk." The tether idea was dropped.

The first photos of McCand-

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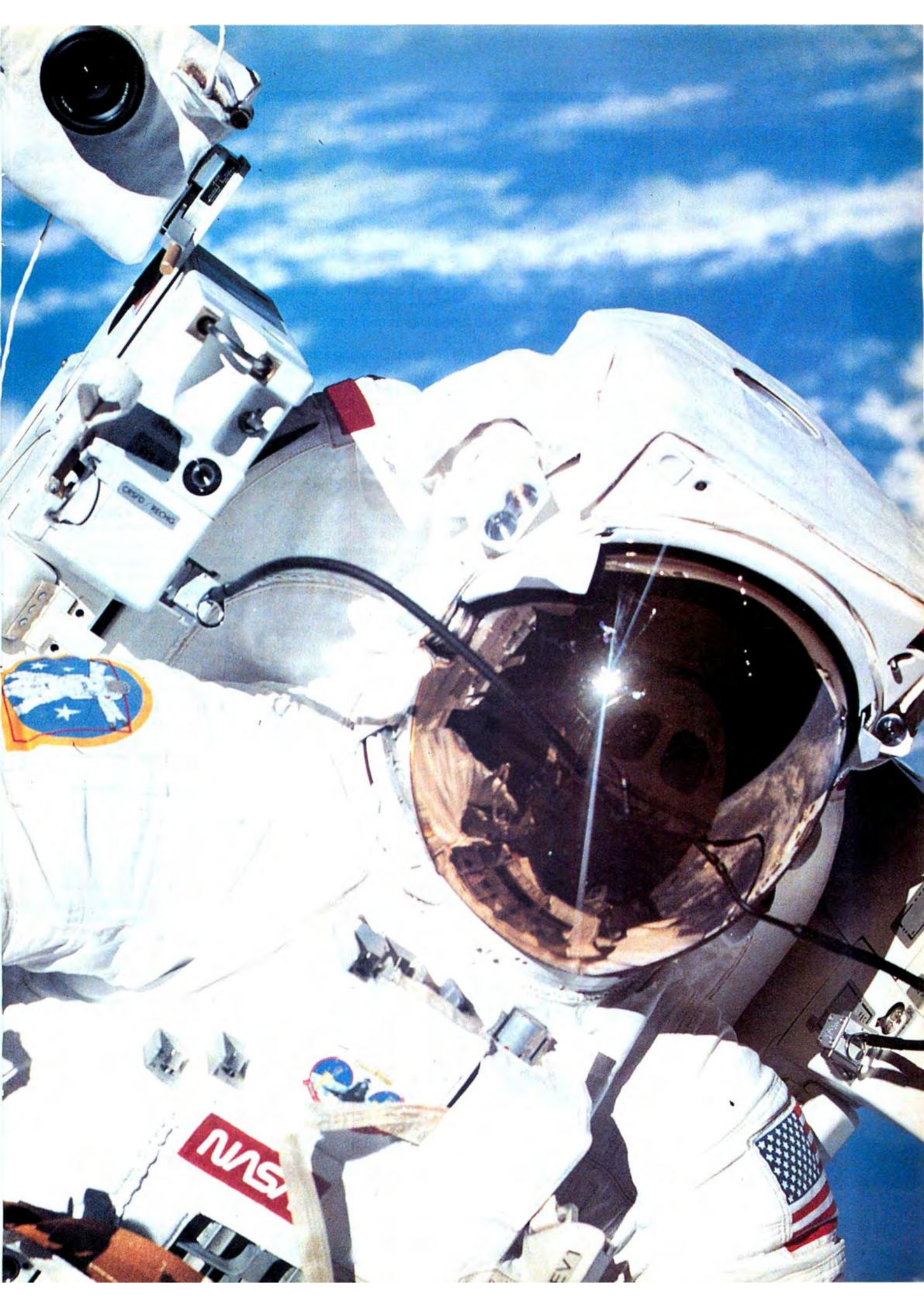
less and Stewart dangling freely above the Earth, set against the black background of space, have appeared in numerous advertisements, magazine and book covers—an image of perfect human freedom and perfect solitude.

But for McCandless, the inner experience contrasted sharply with the outer appearance. "The communications with the orbiter were so excellent, it was like being around a table together talking."

That flight—the one on which McCandless and his crewmate Bob Stewart tested the MMU for the first time—had been dogged by bad luck. The two satellites that were launched from the shuttle, the Westar and the Palapa, both went off course. A primary experiment to release a large balloon and use the shuttle to retrieve it failed when the balloon was inflated—and blew up. "We were in dread that ground control would say, 'Good grief, these guys are having a bad day. Let's cut our



ALL PHOTOS: NASA



JETPACKS OF THE FUTURE

Right now the space backpacks that have performed so flawlessly during satellite repairs and retrievals are in storage. There is one more flight planned for them, a demonstration of space station construction techniques in the early 1990s.

It is possible that the MMUs of the future will have to be modified to accommodate a new spacesuit for space station operations, currently under study within NASA. The astronauts hope for only one improvement in the backpack itself: greater fuel capacity, the one serious limitation of the otherwise excellent equipment. Hand-held range-finders might also be useful if lengthy sorties are planned.

Currently, NASA procedures are strict. Only one astronaut is allowed to use an MMU at any one time. If the equipment malfunctions or fails, the remaining astronaut does not don the additional MMU and go after him. Instead, the orbiter flies over to pick up whoever gets stranded. The rationale is clear: If one MMU failed, the other might have the same problem, and both spacewalkers would be stranded. Also, the shuttle never fires its larger attitude control rockets during MMU operations, to make sure nobody accidentally gets in the way of the rocket plume.

These procedures will have to be rethought in the space station era. Because a space station does not have the maneuverability to pick up a stranded astronaut, a second MMU-equipped astronaut may have to take responsibility for a space rescue.

Some space station planners would prefer to use robotic arms or spacewalkers attached to tethers or exterior handholds to service the space station, instead of using the MMU. But those experienced in the use of the backpack think it would be a serious mistake to neglect the MMU for space station applications. They believe that to throw away a piece of equipment of demonstrated reliability and such great flexibility is just plain crazy. It has earned, they feel, a permanent place in space operations and in space life. □

losses and go home," McCandless said.

Although McCandless felt confident of the equipment he had worked with for so many years, and although he never seemed to suffer from anxiety during the mission, his commander worried constantly: "[Vance] Brand was concerned that I not wander off too far," said McCandless. "He kept saying that if I didn't come back he'd have to face the media—and my wife!"

Although he had planned on doing a full pirouette to look around, McCandless wound up facing either the orbiter or the Earth's surface the whole time he floated 328 feet from the shuttle. "I had planned on it, but it slipped my mind," he said. "The orbiter was in line of sight the whole time—and I concentrated more on it than I anticipated."

Meanwhile, back in the shuttle bay, Bob Stewart was waging a courageous battle with an imperfect spacesuit. The skullcap helmet that contained his earphones and microphone began to come off, and his feet wouldn't stay in the foot

restraints because his spacesuit undergarments were slipping.

"It was terrible," Stewart recalled. "The microphone which was supposed to be around my mouth was up around my eyeballs, so I had to yell to talk. Yelling made my throat dry, but with my helmet almost coming off, I couldn't

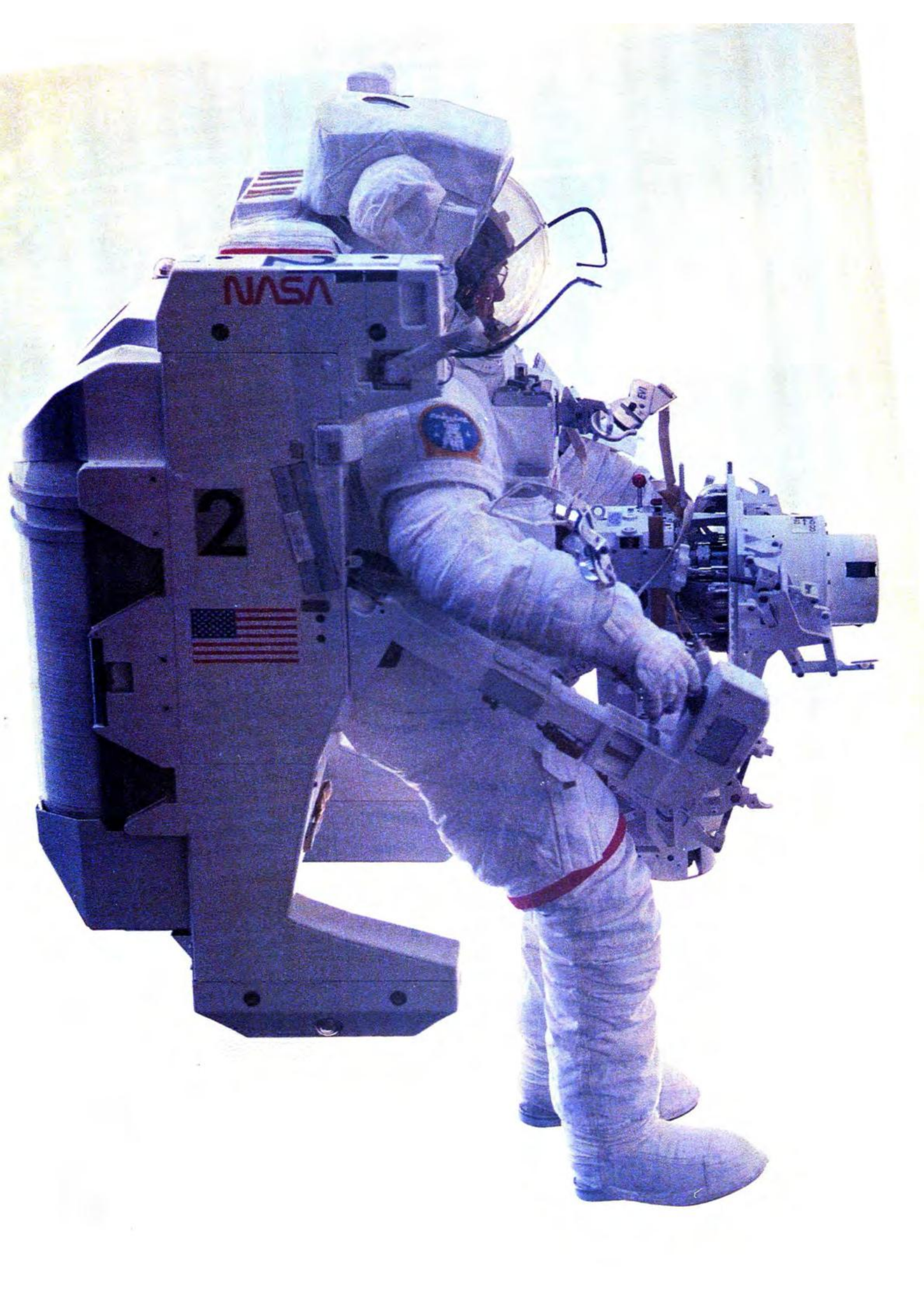
reach my water. My head was, literally frozen inside my helmet to keep from losing my earphones and mikes completely. So there I was with a problem where I couldn't move my head and a problem with my boot that I couldn't investigate because I couldn't move my head."

Nonetheless, Stewart man-

aged to do his work in the payload bay and then don the second onboard MMU to take a glide out over the Earth. "I was afraid the ground [Mission Control] would learn about the problem and make us come back in, so I didn't talk much," he said. "It took the people on the ground almost the entire EVA [extravehicular activity, or spacewalk] to figure out something was wrong, and then they wanted to chatter with me. I kept telling them, I'll just talk to you about it later."

Unlike McCandless, Stewart did turn his back on the Earth and the orbiter to face the blackness of space. "That was very spooky," he said. "I was not prepared for my mental reaction to it. But when I couldn't see the Earth or the orbiter, I spent 10 or 15 seconds like that. And then I got to feeling, 'Boy, it's really lonely out here. Let's turn around and see if the Earth and the orbiter are still there.' It was black, velvety black, and there were no stars because it was daylight. Darkness has been scary since the time we were swinging from trees, and ▶





EXTRA! SHUTTLE UPDATE-MISSION TO VENUS

FINAL FRONTIER

The Magazine of Space Exploration

June 1989

SPECIAL REPORT:

SPACE TOURISM

WHEN CAN YOU GO?

**FODOR'S GUIDE
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**INSIDE: CITIZENS
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DISPLAY UNTIL 6/30/89

2015: THE AGE OF SPACEPLANES

Flying the friendly skies of the future—at Mach 25.

By T.A. Heppenheimer



One by one, the four long, sharp-nosed craft emerge from their Cape Canaveral fueling facilities, towed by a boxy white vehicle hitched to the nose landing gear. Each in turn taxis into position at the end of the runway. A great roar booms across the flat Florida grassland, as a nearly transparent hydrogen flame fills the cavernous exhaust area on each craft's underside and blasts to the rear. Ponderously at first, then with increasing speed, each spaceplane gathers headway, finally zooming from the runway in a swift climb steeper than that of any airliner. Fifteen minutes later the last one is gone, leaving behind only the fading echoes of skyborne thunder.

Although winged spacecraft have been carrying astronauts to orbit since 1981, never before have two vehicles been in flight at the same time. But on this Fourth of July in 2015, a squadron of four American spaceplanes will fly to orbit, virtually in formation. They'll be joined by two European spaceplanes and two from Japan in a dramatic meeting at the International Space Station.

These aren't rocket-powered craft, but true airplanes—able to fly in the atmosphere, reach orbital altitudes above 100 miles and return to Earth at the end of their missions. Both NASA and the Air Force, as well as foreign governments, own and operate these "ultimate aircraft."

The Air Force particularly appreciates the ability to scramble into orbit on as little as an hour's notice. During a military exercise in November 2013, pilots flying F-23 interceptors launched anti-satellite missiles to destroy an obsolete spy satellite in orbit. By the end of the day an Air Force spaceplane had lofted a replacement.

Other spaceplanes fly reconnaissance missions, having replaced the old, slow SR-71 Blackbirds of prior decades. Military planners laud the spaceplane's ability to follow unpredictable paths, unlike the spy satellites whose orbits can be predicted weeks in advance. Reconnaissance spaceplanes can even choose their speed and altitude, descending into the atmosphere to evade killer laser beams or take par-

ticularly sharp photos.

NASA, the Europeans and the Japanese sometimes use spaceplanes to launch satellites, but their prime task is to ferry astronauts to and from orbiting space stations. Back in the days of the U.S. and Soviet space shuttles (and of Europe's smaller Hermes), critics often noted that the work done by astronauts was all very interesting, but that each flight cost up to several hundred million dollars. The advent of spaceplanes early in this century cut the price tag by 90 percent, while reducing the time required to plan a mission from years to weeks.

As a result, the flight of astronauts has become practical and routine. Orbital science has moved beyond the old-time hype about "revolutions" that would spring from work conducted on space stations. The space bases of 2015 are valued for their true worth, as international research centers on a par with the best labs on Earth.

Although they use different techniques to get to orbit, all three spaceplane fleets—European, Japanese and





McDONNELL DOUGLAS CORPORATION



American—are operated like airlines, with small ground crews to prepare the vehicles quickly for flight. This is a marked improvement over earlier space shuttles, which demanded several thousand people working for months before each launch.

Of all the spaceplanes, Europe's Saenger is the least straightforward in its journey to orbit. It features a small winged orbiter, rocket-powered, that rides piggyback atop a hypersonic airplane. Following takeoff from Toulouse in the south of France, the booster airplane cruises at an altitude of 80,000 feet. It heads southwest, around the western bulge of Africa, until it reaches the desired latitude—in this case 28.5 degrees north for a rendezvous with the space station. A satellite launch mission would take it on an equatorial course above the Gulf of Guinea.

In a gradual turn, Saenger heads due east and rises to 100,000 feet. As it flashes across the empty wastes of the Sahara Desert at Mach 6.8, it lays down a heavy sonic boom. The winged mini-shuttle separates and flies to orbit using its own fuel. Meanwhile, the booster airplane turns again and retraces its course back to Toulouse.

Similarly, the winged second stage re-enters the atmosphere and glides from its orbit to the higher latitude of Toulouse. After an unpowered landing, it

U. S. Companies are now competing to design the National Aerospace Plane, shown here in three different artists' concepts. The German Saenger (below) will have a passenger shuttle mounted on a hypersonic first-stage vehicle.

is serviced and reunited with its booster.

By contrast, the Japanese spaceplane packs everything in one single-stage vehicle. Its modified rocket engine "breathes" oxygen from the atmosphere, rather than carrying it in liquid form as an oxidizer to burn hydrogen fuel. This greatly improves the spaceplane's performance, since tanked oxygen is very heavy. (20th century engineers used to quip that carrying liquid oxygen during a rocket's ascent through the atmosphere was like a fish carrying water in a canteen!)

It wasn't easy designing the technology to feed air into the engine, however. Rockets characteristically work at high pressure, and the outside air must be pumped to an even higher pressure to enter the engine. The Japanese design is called "LACE," for Liquid Air Cycle Engine. It relies on supercold hydrogen to chill and liquefy the incoming air. Once in a liquid state, it's easy to pump this air to very high pressures.

Japan's spaceplanes use LACE engines during takeoff and acceleration to Mach 5. By then the craft is at 85,000

feet, where the air becomes too thin to be useful. Only then does the plane switch over to tanked oxygen, proceeding the rest of the way to orbit as a hydrogen-burning rocket.

America's spaceplanes are equally innovative, operating with another new engine called the "ejector scramjet." When the craft flies at high speed, air rushes through carefully-shaped ducts mounted on the underbelly. Fuel injectors then spray hydrogen into this airflow, heating and blasting it out the back to create thrust. But this arrangement needs something extra at both ends of the flight. At low speeds—below Mach 3, for instance—the airflow is too slow for the scramjets to work properly. Above Mach 20, as the craft approaches orbit, the air is too thin.

Small rockets called ejectors solve both problems. During the early stages of flight, the ejector's exhaust plume sucks in a flow of outside air. Hydrogen burned in this airflow adds to the thrust of the ejector, allowing the spaceplane to take off and gain speed. Above Mach 20, this same ejector functions as a rocket in its own right, giving the extra thrust needed to reach orbit.

None of these spaceplanes was created overnight; all trace their origins back to the late 1980s. In Japan, a blue-ribbon space policy committee laid out

continued on page 60



GENERAL DYNAMICS



ROCKWELL INTERNATIONAL



MBB/ERNO

SPECIAL ISSUE! RARE APOLLO PHOTO COLLECTION

FINAL FRONTIER

The Magazine of Space Exploration

August 1989

It was 20 years ago today.



PLUS!

THE MOON IN 2009

VOYAGER MEETS NEPTUNE

**SPACE VISIONARIES
OF THE 1950'S**

USA \$3.50/OTHER \$4.50

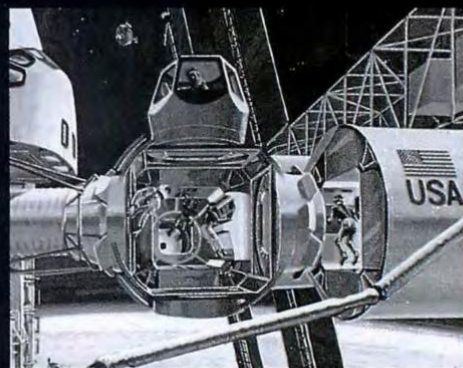


DISPLAY UNTIL 8/31/89

Windows on the World

Space station Freedom's "cupolas" will offer new vistas on heaven and Earth.

BY ALCESTIS R. OBERG



The view is breathtaking, if a little bit odd. In Earth terms, the astronaut is hanging upside down like a bat, watching the world silently go by from a small, cozy perch jutting downward from the far end of space station Freedom, just beneath the shuttle docking port.

After long hours struggling with balky experiments, the tired crew member retreats to this 12-windowed "cupola" overlooking the Earth to experience the beauty of an orbital sunrise—a stereoscopic explosion of light that illuminates Freedom's girders and modules.

As the cupola is flooded with the Sun's bold brightness, the view downward is so unobstructed that the astronaut instinctively grips the nearby handholds. It's easy to forget the day's troubles and remember the reason for becoming an astronaut in the first place—to be here, to see this.

The "eyes" of NASA's orbiting outpost of the 1990s will be a unique new kind of space structure with a quaint, old-fashioned name: cupola. Like the weather-vaned chimneys atop country barns, space station cupolas will have the best view available of the surrounding neighborhood.

The ideal structure for a panoramic view of space would be a giant glass dome similar to the navigation "bubbles" that long-range aircraft used to carry. But a glass bubble in space would be an accident waiting to hap-

pen. One small puncture from a piece of orbital debris could cause sudden decompression, and the dome would explode like a bomb.

So designers of the space station cupola have fallen back on tried-and-true flat windows, arranged on an octagonal framework—four windows on top, and eight around the side. From inside, the view is something like being inside a fly's eye.

Two cupolas are planned for Freedom: one "Earthside," with a view of the underside and lower booms of the station, and the other on top, with a view of the upper part of the structure as well as the stars.

Two people can fit inside each cupola if they stand shoulder-to-shoulder. The current mockup at NASA's Johnson Space Center, built by space station contractor McDonnell Douglas, is about six feet tall. With an adaptor connecting it to a hatchway in one of Freedom's resource "nodes" (short sections linking the larger cylindrical modules), an astronaut could squeeze his or her entire body inside the cupola, and still be able to close the hatch. Other designs for a shorter cupola would accommodate astronauts only from the waist up, with their legs dangling down into the node.

Despite the spectacular view, sightseeing will be only an incidental activity inside the cupolas, which are the primary nerve centers for monitoring the exterior of the station and the space around it. Whatever operations are happening outside the station, astro-

continued on page 68

Freedom's cupolas (shown in mockup, left and center) will provide a spectacular perch for Earthgazing astronauts. They also will serve as the station's nerve center and (right) as a control tower for shuttle dockings.



THE FUTURE *as it was*

Back in the 1950s, Von Braun & Co. had a grand space program ready to go. All it would take was time and money.

By Les Dorr, Jr.

When *Collier's* magazine hit the stands on March 22, 1952, many of the weekly's loyal readers probably did a quick double take. In place of the usual fluffy cover art, a sleek black rocket ship blasted its way into the heavens, leaving a spent, glowing booster stage behind. "MAN WILL CONQUER SPACE SOON" the cover blurb proclaimed urgently, adding that "Top Scientists" would explain it all in "15 Startling Pages."

Inside, rocket wunderkind Wernher von Braun and science popularizer Willy Ley laid out a vision that was fantastic for those pre-Sputnik days: an orbiting wheel-shaped space station crewed by 80 people...a mammoth launch vehicle with 28 million pounds of thrust...astronauts zipping back and forth in "space taxis." Just give us, they said, ten years and four billion bucks—about a quarter of the Defense Department budget for 1951—and *pax Americana* will reach outward to the stars.

As a nation, we were already becoming space-happy. Kids vegetated in the baleful light of the TV tube as the stalwart heroes of *Tom Corbett*, *Space Cadet* and *Space Patrol* efficiently dis-

patched galactic villains or the alien-of-the-week. And moviegoing adults had goggled at the special-effects magic in *Destination Moon*, which had realistically (for 1950) depicted a piloted lunar flight.

Collier's wasn't even the first place where space travel had nudged its way out of the realm of pulp science fiction and demanded to be taken seriously. The same Willy Ley—a paleontologist by training, science writer and co-founder of the German Rocket Society by avocation—had produced popular books on rockets and missiles since coming to the United States before World War 2. In 1949, he authored *The Conquest of Space*, a fact-based blueprint for voyages around the Earth and beyond. Ley's heady text was punctuated by the striking illustrations of cosmic artist Chesley Bonestell, already well-known for his planetary landscapes.

Ley's book sold well, but *Collier's* represented a quantum leap in readership. The decision to run a large, colorful spread on space travel was the collective brainchild of several members of the magazine's editorial staff, who had attended the first symposium on the topic late in 1951. Associate editor Cornelius Ryan, who later wrote *The Longest Day* and other popular accounts of World War 2, was assigned to coordinate the project.

In "Crossing the Last Frontier," Wernher von Braun described a typical orbital flight aboard a winged shuttlecraft. He packed an enormous amount of detail into a six-page article: specifications for a 240-foot-tall rocket booster, possible launch sites (one was "the Air Force Proving Ground at Cocoa, Florida," later and better known as Cape Canaveral) and speed and altitude checkpoints along the vehicle's flight path.

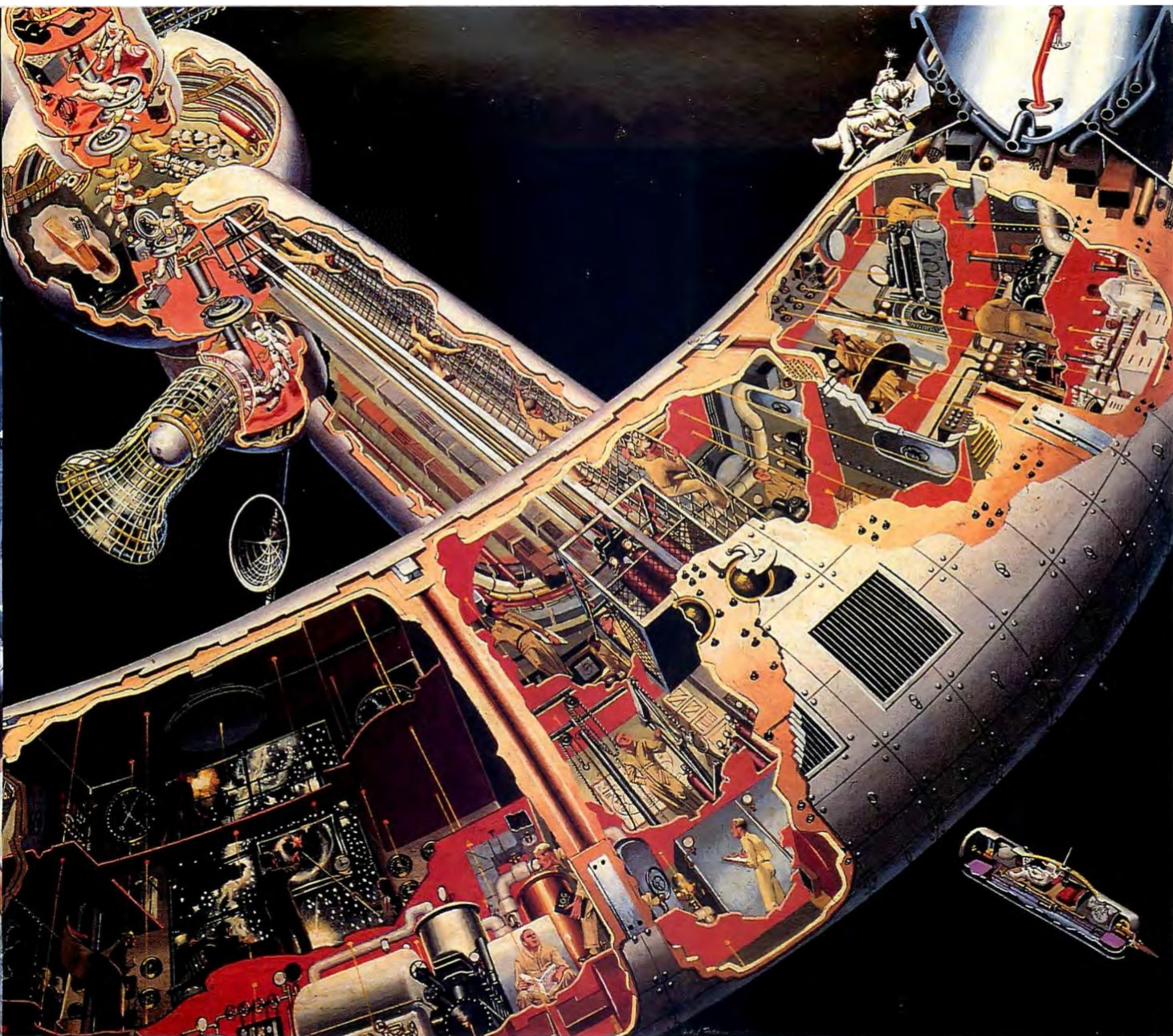
Von Braun had his proto-shuttle rendezvous with a 250-foot-wide inflatable space "wheel" spun to produce artificial gravity. In a separate article, Ley described the minutiae of the station's interior, relating how astronauts would live and work "under conditions comparable to those on a modern submarine." A third feature by Heinz Haber of the Air Force School of Aviation Medicine was a primer on the biomedical hazards that would be faced by space voyagers. Despite the unknowns,



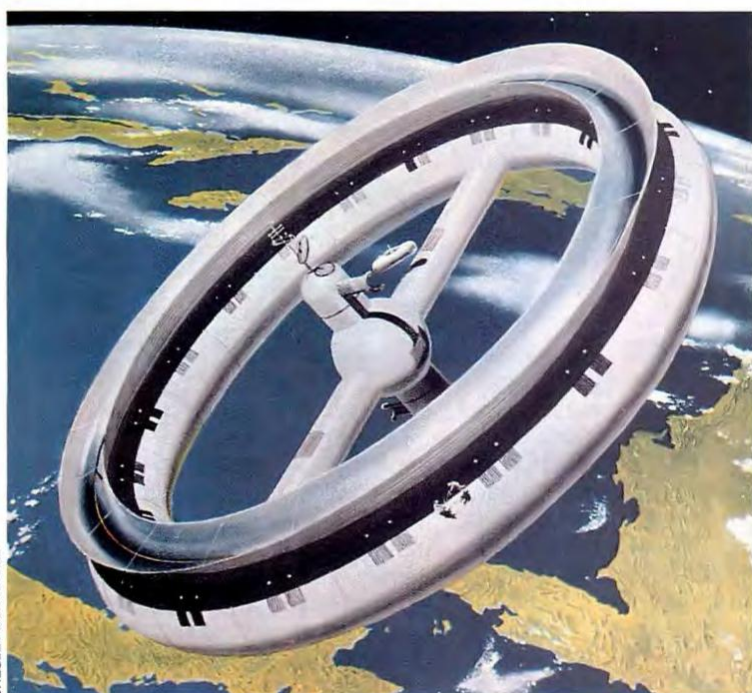
Haber wound up on a positive note: space travel would probably be safer than "crossing a busy street at rush hour."

Later astronauts would sail off into the heavens "for all mankind," but there was no altruism behind the *Collier's* articles. The Korean War was still raging, and Americans were looking for a Red under every bed. The magazine's editors warned that if the United States declined to secure "space superiority," it faced the specter of a "ruthless foe"—read Stalin's Soviet Union—ensconced on an orbiting battle station, from which it could "subjugate the peoples of the world." Von Braun himself echoed that sentiment, casually noting that a space station would make "a terribly effective atomic bomb carrier."

Collier's brought Ley and von Braun back for an encore in October 1952.



FRED FREEMAN/SPACE ART INTERNATIONAL



CHESLEY BONESTELL



ROLF KLEP/SPACE ART INTERNATIONAL

Sound familiar? A large, Earth-orbiting space station (left, and cutaway at top) was von Braun's stepping-stone to the Moon and Mars. He also envisioned astronauts zipping through space with hand-held maneuvering units (above).

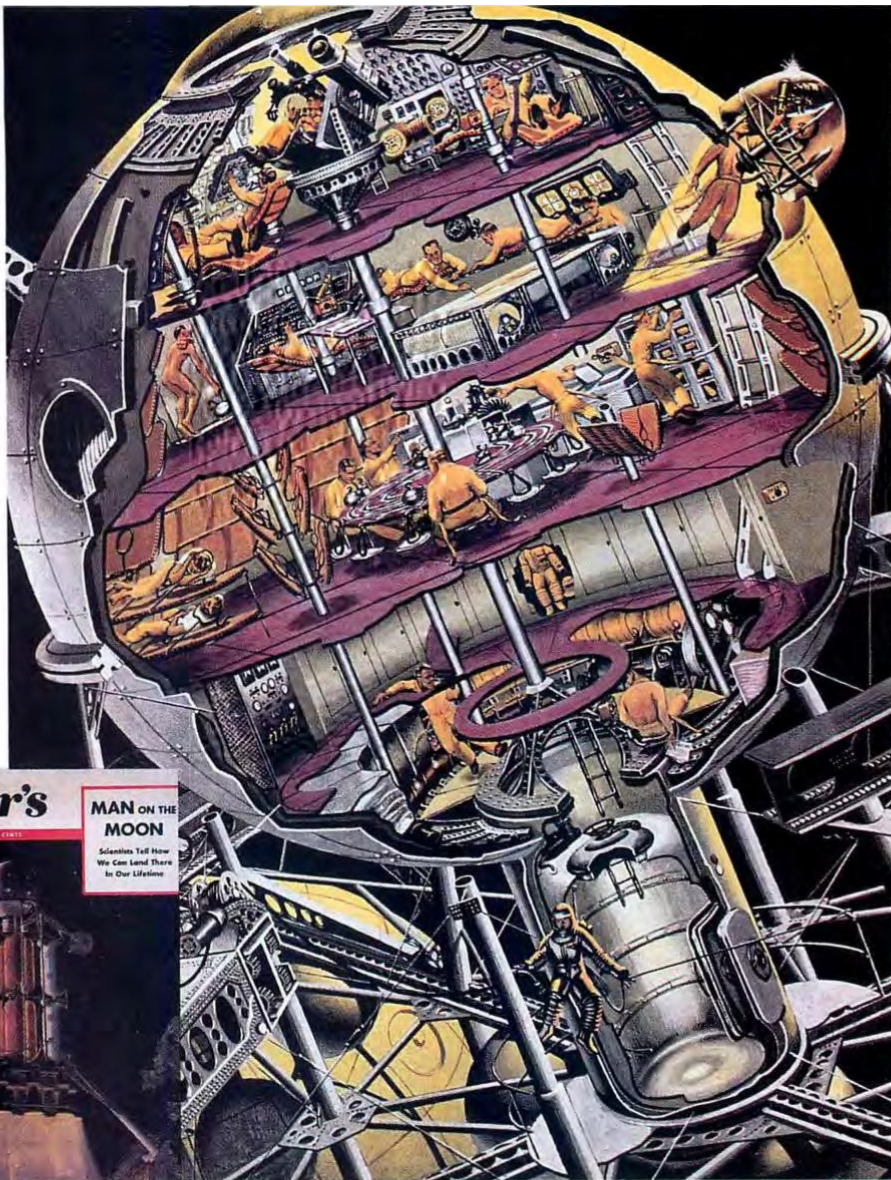
Willy Ley's Moon ship (right) included bath stalls and microwave ovens. (Below) Chesley Bonestell's lush artwork depicting a Mars expedition.

With the Red Menace presumably Earthbound and under control, it was time to conjecture about one of humanity's oldest dreams—a landing on the Moon.

Today, the grand scope and audacity of von Braun's first lunar expedition seem almost comical. Ever the dreamer, von Braun postulated a crew of fifty astronauts, aboard three great spidery Moonships built in Earth orbit over a period of months, who would land in the northernmost part of the Moon's Ocean of Storms by 1977. Scientist and engineer von Braun kept his explorers busy: During a six-week stay, they tore down their cargo ship to construct a base, chugged off in Moonbuggies to scout an area the size of the northeastern United States, and scaled the rim of Harpalus crater. As a finale, a solitary Moonwalker was lowered—by rope—11,000 feet to the crater floor.

Once again, Ley tackled the technical description of the astronauts' home away from home. On the Moon-bound spacecraft, his passengers ate frozen foods zapped in a microwave and took sponge baths in a stall (a *la* Skylab of two decades later). His lunar base was less visionary. Except for the solar-heated mercury vapor power generator, Ley might have been describing an early 1950s Antarctic camp.

Not everyone was quite as ready to jump on the futuristic bandwagon as *Collier's*. Noted space historian Frederick C. Durant III, then vice president of the American Rocket Society, recalls that one major rocket company passed the word it would withdraw corporate sponsorship "if the Society didn't stop all this 'foolishness' about spaceflight." And in announcing Arthur C. Clarke's non-fiction treatise *The Exploration of Space* as one of its July 1952 selections, the Book-of-the-Month Club felt compelled to assure members it hadn't



FRED FREEMAN



CHESLEY BONESTELL/SPACE ART INTERNATIONAL

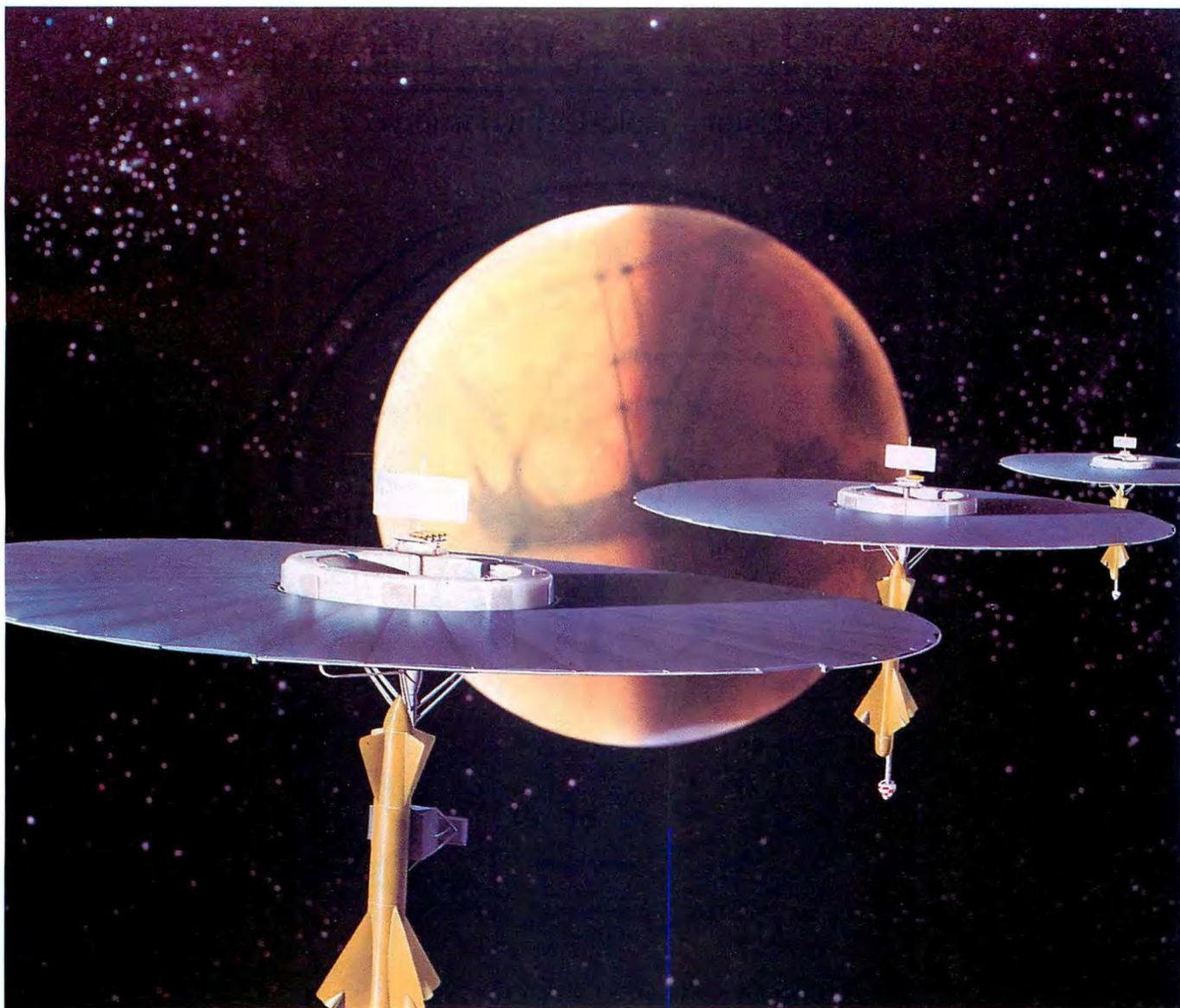


gone nuts. The group admitted the offer of Clarke's book might seem "a fantastic gesture" to its level-headed members; certainly the judges had never made "an odder choice," but they hoped readers would find it "rewarding."

Collier's returned to space, so to

speaking, in the spring of 1953 with a three-part series on the human aspects of rocket-powered flight. There were no dramatic bylines this time, but editor Cornelius Ryan drew on material provided by von Braun, Ley, James Van Allen (discoverer of the eponymous radiation belts) and aerospace medical experts such as the Haber brothers, Heinz and Fritz.

In successive weeks, the articles



THE WALT DISNEY COMPANY

spelled out the process of selecting and training the brave young men who would fly into space. And yes, there was even a place for women as radio and radar operators, *Collier's* noted, because they had demonstrated the ability to "perform monotonous tasks ... without undue loss of efficiency."

This was six years before the original Mercury astronauts were chosen, yet *Collier's* qualifications for space flyers epitomize nearly all the Right Stuffers: age between 28 and 35, with medium build; height, 5'5" to 5'11", with a college degree or equivalent.

The 1953 series on making a "space man out of an Earth man" may have lacked the daring and originality of the earlier articles, but *Collier's* didn't disappoint its fans the following year. Timed for the closest approach of Mars in 13 years, the last of the magazine's classic features reunited von Braun's straightforward prose with Chesley Bonestell's stunning visuals to paint a



THE WALT DISNEY COMPANY

realistic portrait of a 21st Century voyage to the Red Planet.

Mars and von Braun were old friends. Even as he helped the U.S. Army shoot off captured V-2s during the late '40s, the German rocket pioneer had minutely planned a "Marsprojekt" to send ten spaceships and 70 astronauts on an excursion to survey the Martian surface.

Von Braun drew heavily on his study (published in English in 1952 as *The* continued on page 64



THE WALT DISNEY COMPANY

Walt Disney (second from right) hired von Braun, Ley and Heinz Haber to bring their visions to television. Millions of viewers watched astronauts assemble a space station (above) and a space fleet sail for Mars (top).

The last 10 miles were on us!

APOLLO 11



On July 20, 1969, NASA's Apollo 11 Lunar Module—the Eagle—landed men on the moon for the first time.

The Eagle was gently lowered to the lunar surface by the TRW-built Lunar Module Descent Engine (LMDE).

Six LMDE's landed modules on the moon. LMDE also thrust the aborted Apollo 13 and its crew into a safe return trajectory.

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P. J. Wetzel

W

e remember that summer night twenty years ago the way we remember the other cultural earthquakes of the 1960s: the assassination of a president, the arrival of four mop-topped singers from Liverpool, the violence in a faraway place called Vietnam. Like those other events, we experienced it mainly through television. But unlike the others, it still seems, even after twenty years, like a fantasy. We watched a ghostly figure descend on our T.V. screens into an odd jumble of light and darkness. We heard his voice, speaking from such unimaginable distance that his words arrived a long moment after he spoke them. Yet one of the miracles of this midsummer night's dream was that the voice was clear. The figure stood in the shadows, then took a step. There was a pause in the stream of high technology jargon, and we heard a single sentence: "That's one small step for man, one giant leap for mankind." Minutes later, the lone figure was joined by a second, and the two danced in slow motion long into the night, like snowmen brought to life. And the dream was over. ■ Yet it had all been real. Neil Armstrong and Buzz Aldrin actually had done what seemed like science fiction only a decade earlier; they had walked on the Moon. For a moment we were awed; then, as the 60s became the 70s, we lost interest. Other astronauts followed Armstrong and Aldrin to the Moon, their scenes played out on our televisions with ever greater clarity. But by the time the last explorers left the Moon in December 1972, we had stopped watching. ■ Twenty years later, their photographs remain; pictures of men walking on the Moon are as familiar as Warhol's soup cans. We have barely come to terms with the events they record, yet the pictures are as sharp and vivid as ever. Looking at them, we feel the rush of oxygen past our face as we peer out from within a pressurized spacesuit. We hear the soft hum of the machinery that keeps us alive in the vacuum of space. We feel the buoyancy of lunar gravity, and we gaze out at a landscape of stark and alien beauty. And we discover how it really was to be on the Moon.



By ANDREW CHAIKIN

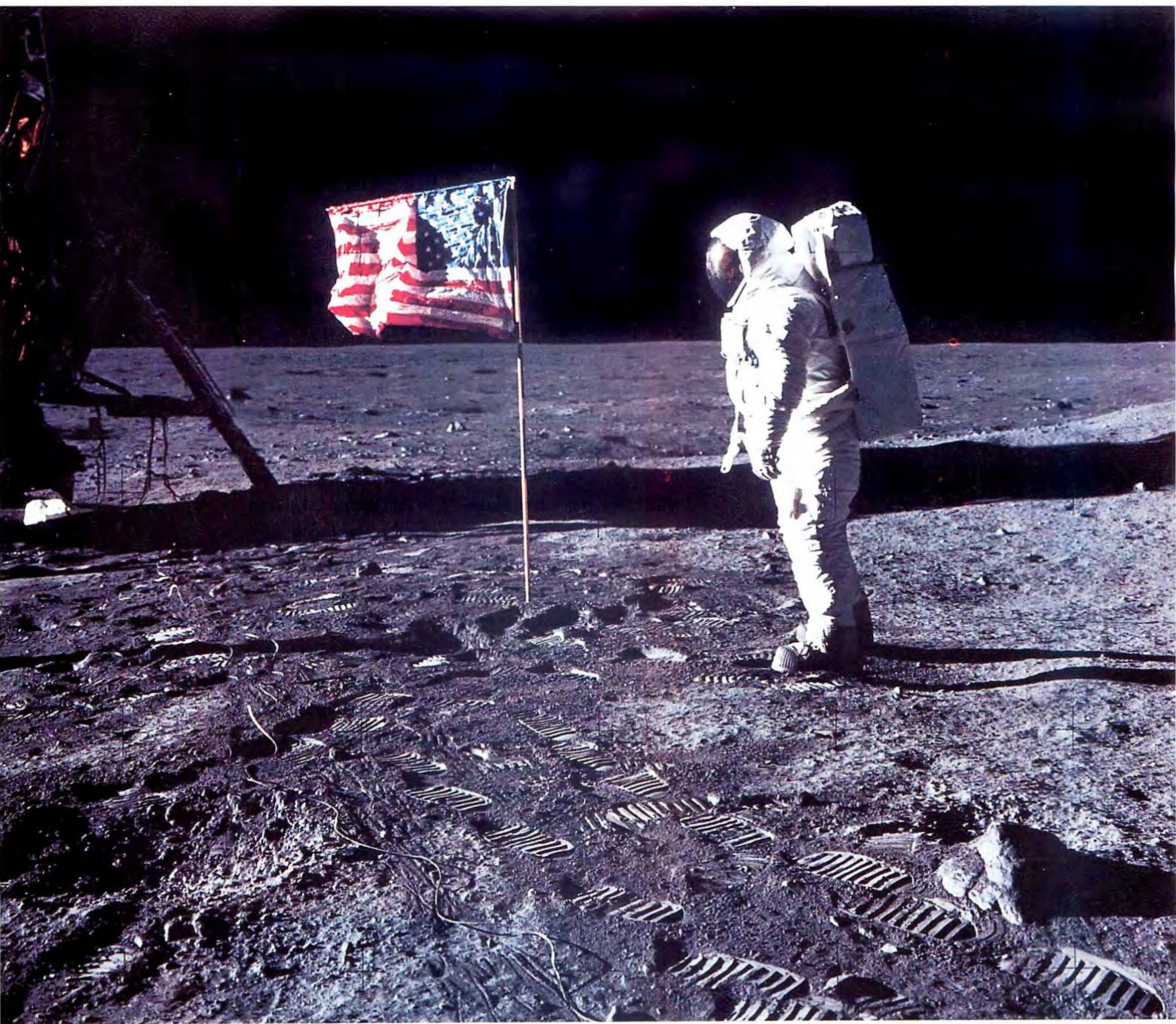


Apollo 11 Minutes after taking his "one small step," Neil Armstrong snapped the first photo taken by a human being on another world (top). The bag next to the lunar lander contains empty food bags and other items discarded to save weight on the trip home. Armstrong was on his way back from photographing a large crater when he recorded this view of "Tranquility Base" with his own shadow (above). Because he took most of the pictures on the surface, there are almost no clear views of Armstrong on the Moon.

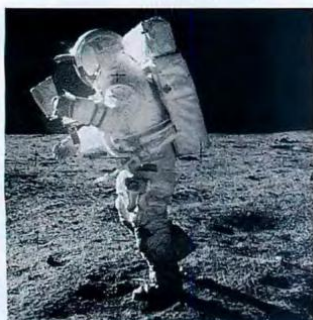
The flag didn't want to stay up; it almost fell over in the dust while a billion people watched on live television. But with Buzz Aldrin's help, Neil Armstrong finally got it to balance. Then, as Aldrin stood at attention before the wire-stiffened banner, Armstrong backed away and snapped this timeless image of a human being planting a flag on another world.

If they had done nothing more than return to Earth with this one photograph, the astronauts would have fulfilled Apollo's mission. But in a brief Moonwalk lasting only two and a half hours, Armstrong and Aldrin also collected rock and soil samples, laid out a collection of scientific experiments and took dozens of stunning photographs of the Sea of Tranquility's stark beauty. The Moon was a place of ancient and untouched magnificence, a museum world preserved nearly unchanged for three billion years.

The landing itself had been hair-raising. An overloaded computer threatened to abort the mission while Armstrong and Aldrin were still thousands of feet above the Moon. In the final minutes of the descent Armstrong was forced to take over manual control to avoid a huge crater strewn with boulders. At last he found a smooth, safe spot about four miles from the planned landing site. With only seconds of fuel left, amid a flurry of dust stirred up by the descent rocket, Armstrong brought *Eagle* down onto the surface so softly that neither he nor Aldrin felt the touchdown. The critical liftoff from the Moon, the rendezvous with Michael Collins in lunar orbit and the trip back to Earth were still to come. But for a moment, as stillness returned to the Moon, the first visitors to another world turned to each other and shook hands without saying a word.



WALKING



Apollo 14 Map in hand, Ed Mitchell heads for the top of Cone Crater.

The astronauts who followed Armstrong and Aldrin to the Moon had more on their agenda than just landing and stepping outside. The next two teams of explorers each stayed half again as long as Armstrong and Aldrin had, and took two Moonwalks each, totalling roughly eight hours. The first excursion was limited to setting up an automatic science research station, but the second walk was for exploration. In their quest for the Moon's geologic treasures, these teams of astronauts journeyed on foot up to a mile or more from the safety of their lunar module without fear, putting all confidence in their equipment.

Just moving about on the Moon was a delight. Despite the great bulk of the suits and backpacks—on Earth they would have weighed 350 pounds—the Moon's 1/6-gravity made walking nearly effortless. To Apollo 12's Alan Bean it seemed, during a long run from one crater to another, that his legs would never get tired. Just push off with the toe, soar into space, and land. The astronauts learned to rock from side

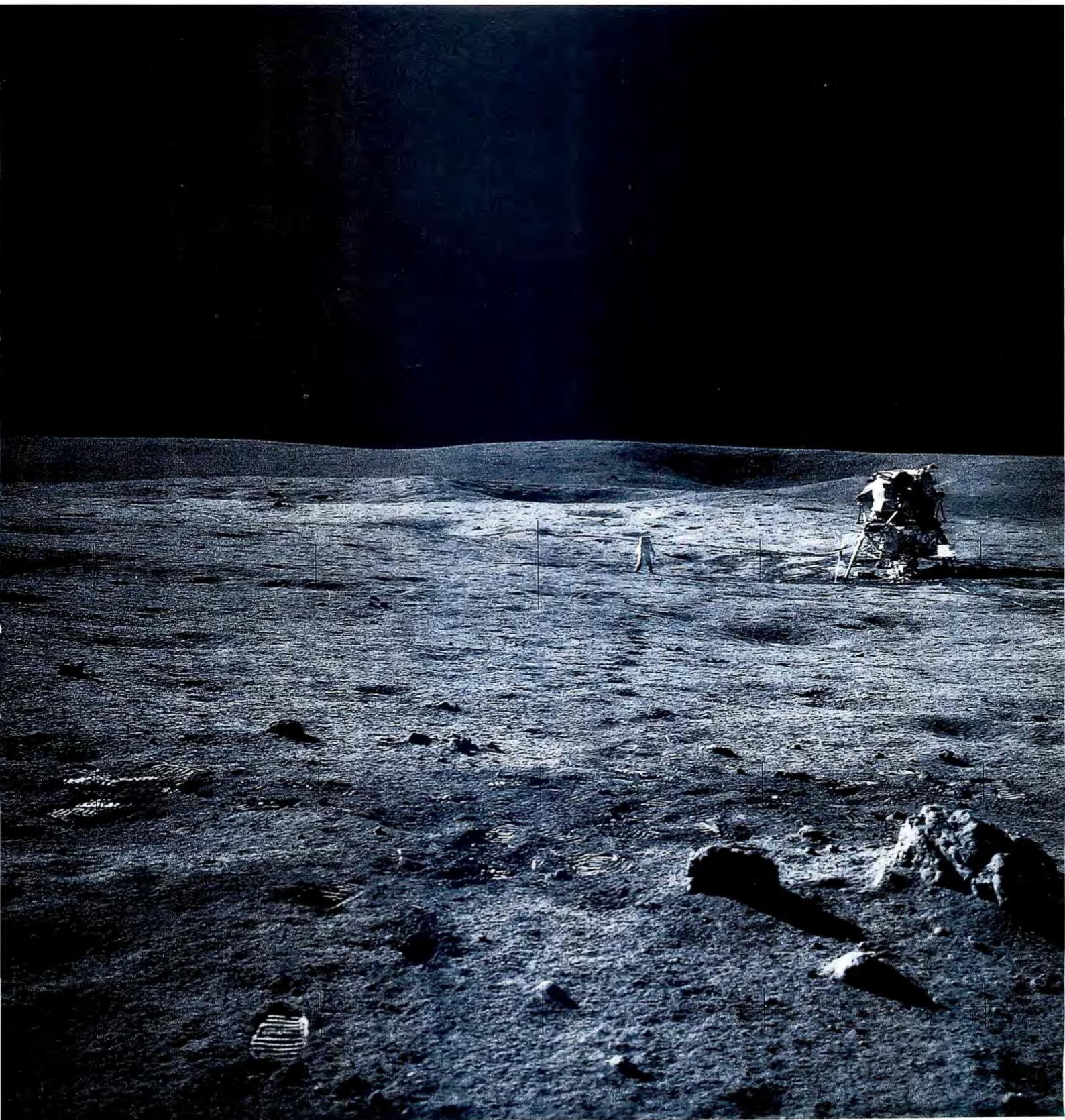
to side as they ran, creating a new form of locomotion: the lunar lope.

The problem was navigating. On this airless world everything was so unnaturally clear that the astronauts found they had almost no ability to judge distances. And even with photo-maps supplied by the geologists, they had great difficulty recognizing the craters that were their landmarks, hidden as they were in a sea of undulating hills and hummocks. These problems thwarted Alan Shepard and Ed Mitchell of Apollo 14 as they climbed the flanks of Cone crater. They searched for the crater rim until they ran out of time; only after they were back on Earth would they learn that they had missed their objective by only 75 feet.

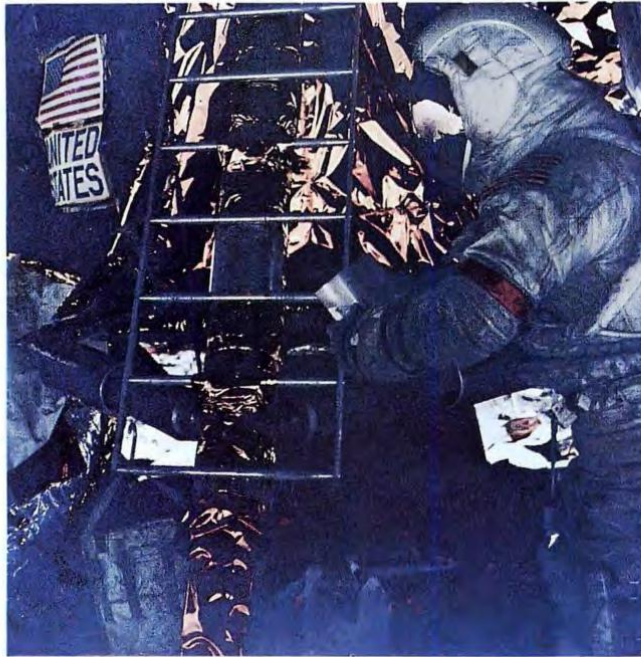
But Shepard and Mitchell had at least reached the Moon. Their predecessors—James Lovell and his Apollo 13 crew—were almost marooned in space when an explosion crippled their spacecraft 200,000 miles from Earth. Apollo 13 reminded everyone that going to the Moon was, above all, a risky enterprise.



Apollo 14 First steps: Alan Shepard shades his eyes from the full-strength lunar sunlight.



Apollo 14 Explorer in an ancient wilderness: Shepard roams the undulating plains of Fra Mauro.



Apollo 17 Gene Cernan at the base of the lunar lander, covered with three days' worth of grime.



Apollo 17 The man inside the space suit: Jack Schmitt had raised his reflective, outermost visor for a better view when he was caught by the ground-controlled TV camera during the last of three Moonwalks.

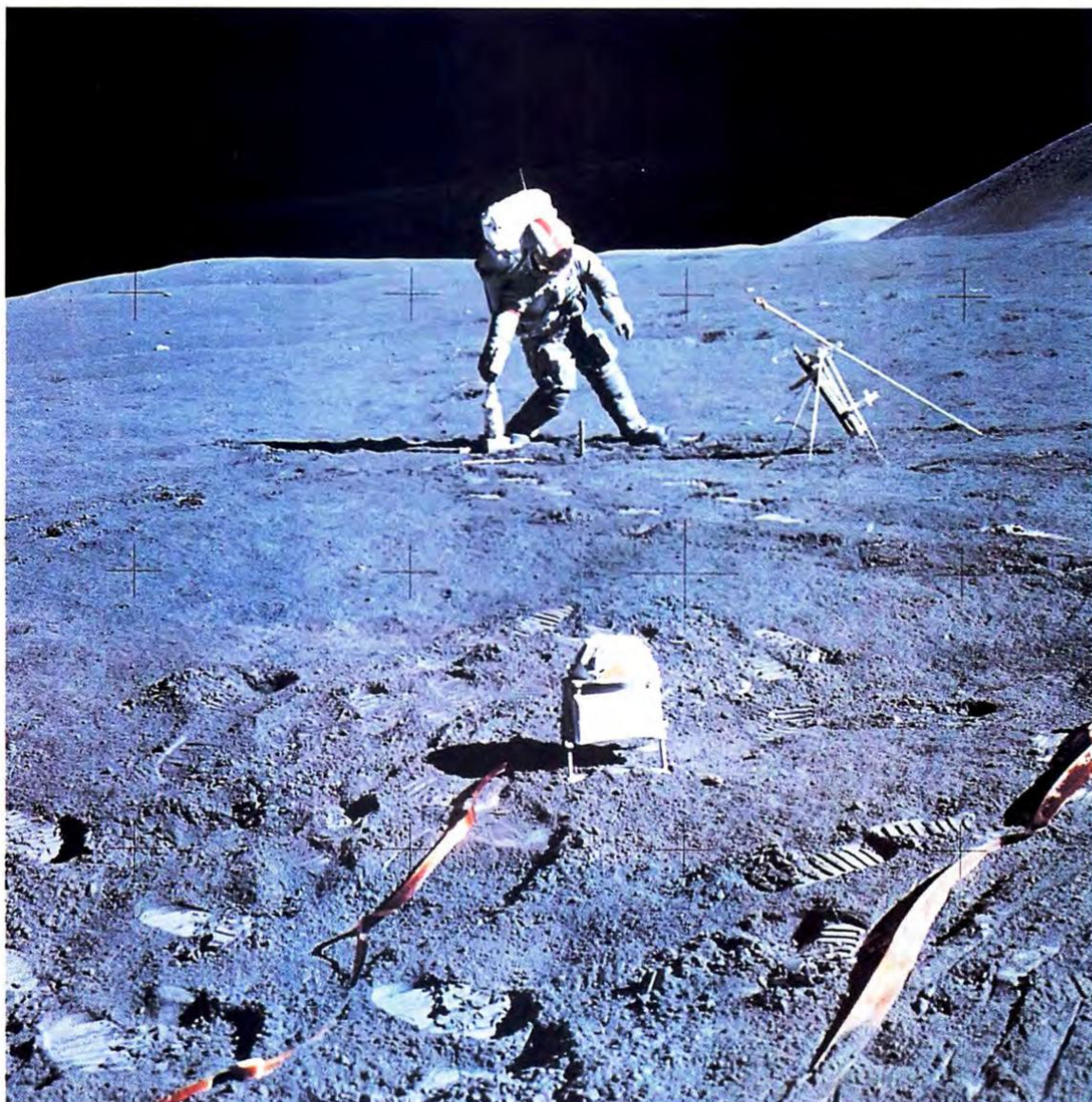
Apollo 11 (right) Buzz Aldrin carries experiment packages to be set up on the lunar surface.

If walking on the Moon was fun, just about everything else was hard work. Dust was a constant impediment. The fine, soft soil—as fine as talcum powder—stuck to everything that touched it. Keeping anything clean—cameras, charts and especially themselves—was a constant struggle. By the end of a long outing, the Moonwalkers looked like chimney sweeps.

The astronauts were constantly fighting the stiffness of their pressurized spacesuits, especially their gloves. Every movement of the hand was like squeezing a hard tennis ball. Tasks that would have been simple on Earth—picking up rocks, twisting sample bags closed—required great effort. Their fingernails, which constantly rubbed against the ends of the gloves, were as sore as if they had been hit with a hammer. By the time they climbed back into the lunar module, the astronauts were nearly exhausted.



But two things distracted them from these hardships: the excitement of being on the Moon and, above all, the relentless pressure of time. No one who went to the Moon felt that he had enough time to do the work on his checklist. Always, there was a voice in his ear—the voice of Mission Control on Earth—calling him to the next task. Near the end of a seven-hour Moonwalk, Dave Scott had to stop and laugh: he had two checklists on his wrists, each telling him to do something different at that very moment.



Apollo 15 Some of the hardest work on the Moon was spent operating a battery-powered lunar drill. Here Dave Scott labors to make a hole in the ground for a scientific thermometer.



Apollo 17 Lunar rake in hand, Jack Schmitt goes prospecting at the boulder-strewn rim of 2,100-foot Camelot Crater.



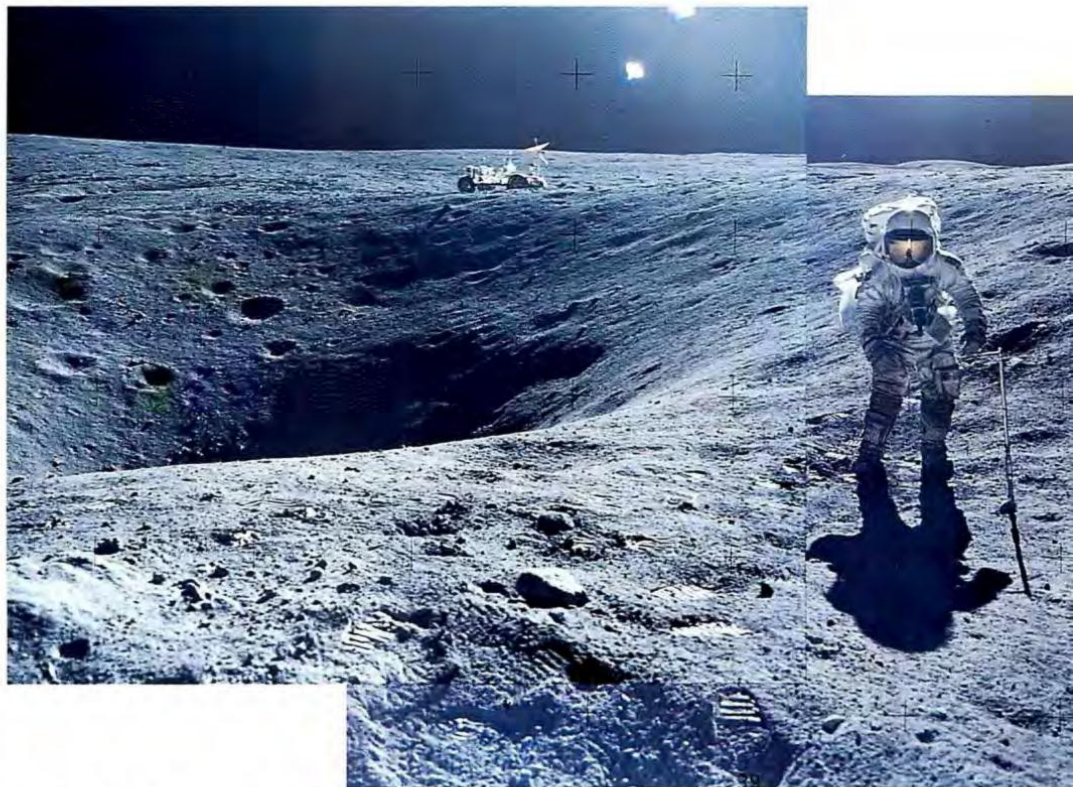
Apollo 15 High on the slopes of Hadley Delta mountain, Dave Scott takes a picture of a geologic find before picking it up.

By the time they reached the Moon, the Apollo astronauts were trained lunar field geologists. Each team of explorers strove to do more than the ones before them—travel farther, bring back more rocks, more photographs, more data. Especially on the rover missions, they covered a wide variety of terrain types. To them, the ubiquitous lunar craters were like excavations that had brought precious samples of the lunar crust to the surface.

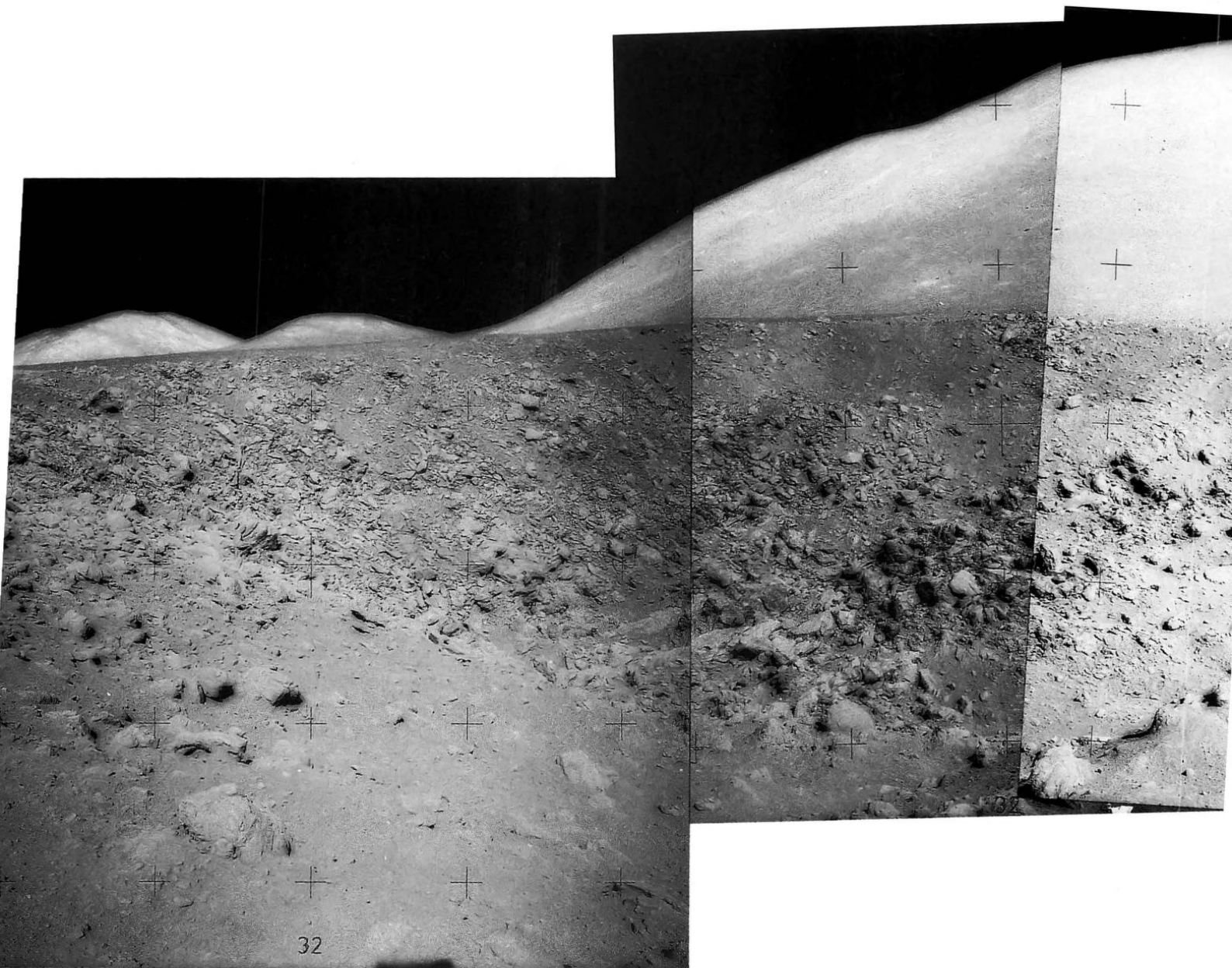
Before his Apollo 16 landing, John Young had thought about bringing a rope along to help him and Charlie Duke explore the huge North Ray crater, but NASA managers were too nervous about the idea to approve it. When they reached North Ray, Young and Duke stayed well away from the crater rim, knowing that if one of them fell in, he would never be able to climb back out.

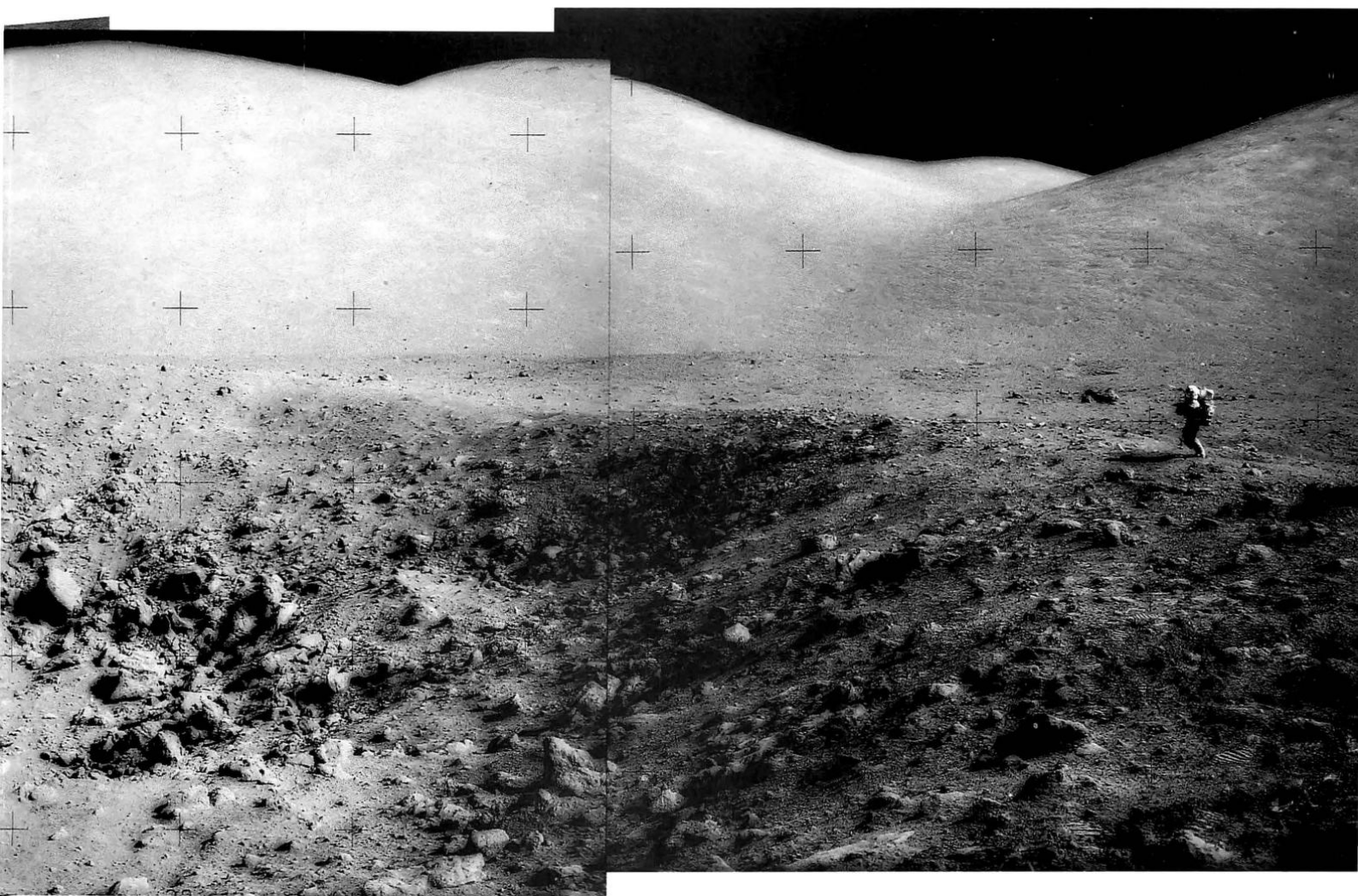
Some of the most spectacular—and exhausting—explorations came on the slopes of the lunar mountains. The rover climbed with such ease that when the astronauts got off to walk they were startled by how steep the mountainside was. Climbing on foot, they soon found, was a tremendous drain of energy. But here were some of the most valuable prizes: samples of the oldest crust of the Moon, nearly as old as the Solar System itself. The view from these high slopes, with the lunar module a tiny dot in the great primordial wilderness, was described by John Young as “one of the most truly beautiful views ever seen by a human being.”

But there was never any time to freelance, to look around and investigate something interesting. Even the moments of awe and personal discovery were fleeting. They would not be experienced fully until after the mission was over, in retrospect, if ever.



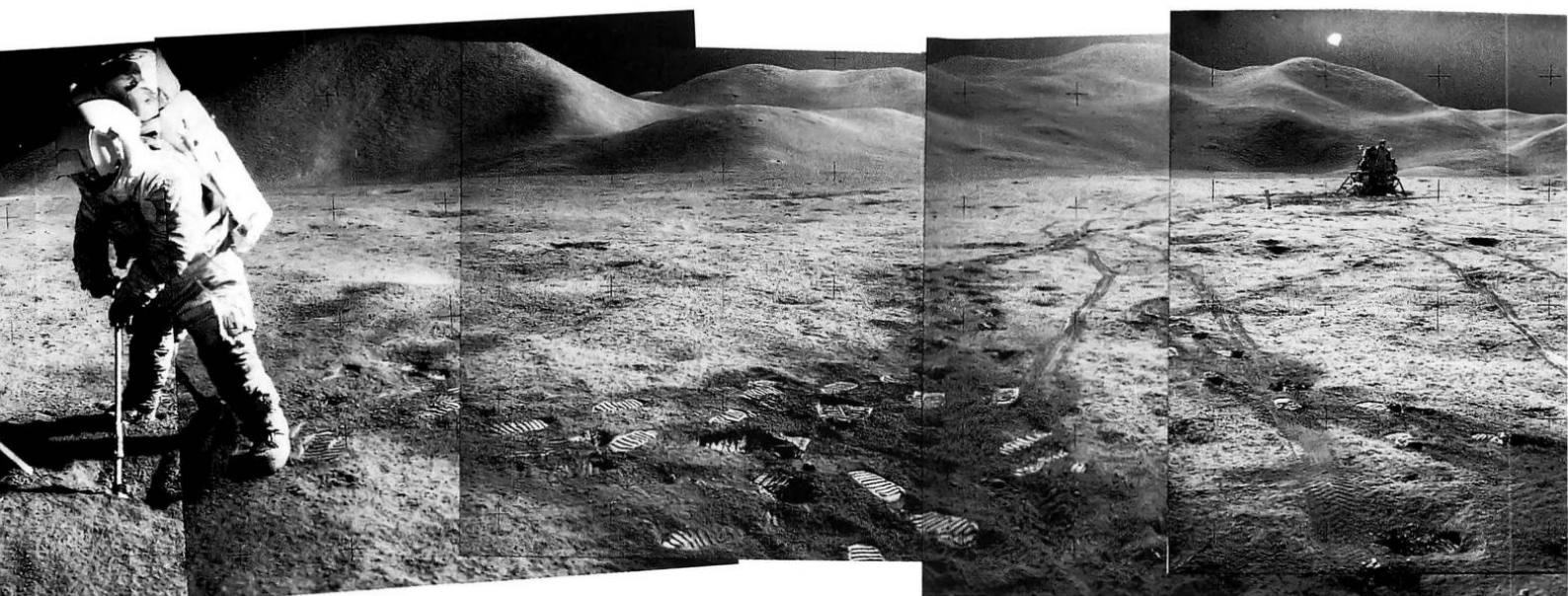
Apollo 16 In a landscape battered by billions of years of meteorite impacts, Charlie Duke poses next to one of the smaller craters he and John Young visited, 100-foot Plum Crater.





Apollo 17 Jack Schmitt pauses to take photographs at the edge of 260-foot Van Serg crater while Gene Cernan records the scene in this series of panoramic photos. In the background, less than two miles away, North Massif rises 6500 feet to dominate the skyline.

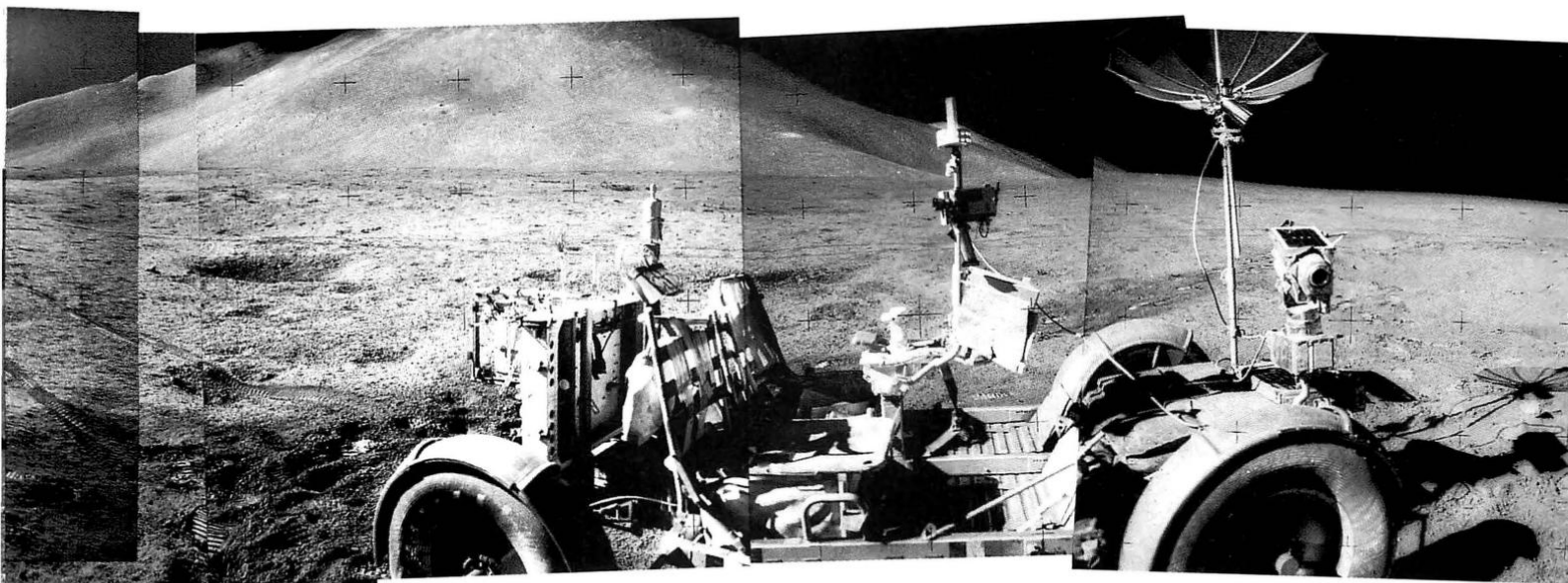
A LUNAR BASE



Apollo 15 *Panorama at Hadley Base.*



Apollo 15 *The lunar lander (background) and rover at Hadley.*



With the final three landings, lunar exploration entered a new phase. The astronauts of the Apollo 15, 16 and 17 expeditions thought of their missions as a different experience from the earlier landings. They wore upgraded backpacks and improved suits, which allowed them to work outside for up to seven hours at a time, nearly a full working day. Driving a battery-powered car called the rover, they could range several miles from their base camp. They had to pace themselves; a good night's sleep, which had eluded earlier crews, was now essential. The later explorers didn't just visit the Moon; they lived there for three days.

On these extended expeditions, some of the Moon's most spectacular scenery was now within reach. On Apollo 15, Dave Scott and Jim Irwin set down on a broad lava plain at the foot of the Moon's Apennine Mountains. They drove their rover among

the craters, to the edge of a winding valley called Hadley Rille, and up the side of Hadley Delta mountain.

In this panorama, photographed by Scott late in the second of three Moonwalks, Irwin is digging a trench to investigate the nature of the lunar soil. In the center, framed by the distant peaks, sits the lunar module *Falcon*. At right is the rover, its tracks criss-crossing the ancient ground.

Even with three days on the lunar surface, the astronauts found they could not accomplish everything they wanted to do. The day after these pictures were taken, Scott and Irwin struggled so long with pulling a stuck lunar drill from the ground that they had to give up one of their most exciting geologic excursions, a visit to a puzzling field of craters called the North Complex. Like all the astronauts, Scott and Irwin left the Moon feeling they had only begun to explore its mysteries.



Apollo 15 A proud moment: Dave Scott salutes the flag.



Apollo 15 Rover tracks.

As they go about their lives, the men who went to the Moon rarely look back on Apollo unless someone asks them about it, which happens more often than any of them prefer. But some moments remain vivid in their consciousness: the mixture of pride and humility that came as they stood before the flag, the thrill of geologic discovery, the moments of humor, of surprise, of exhaustion.

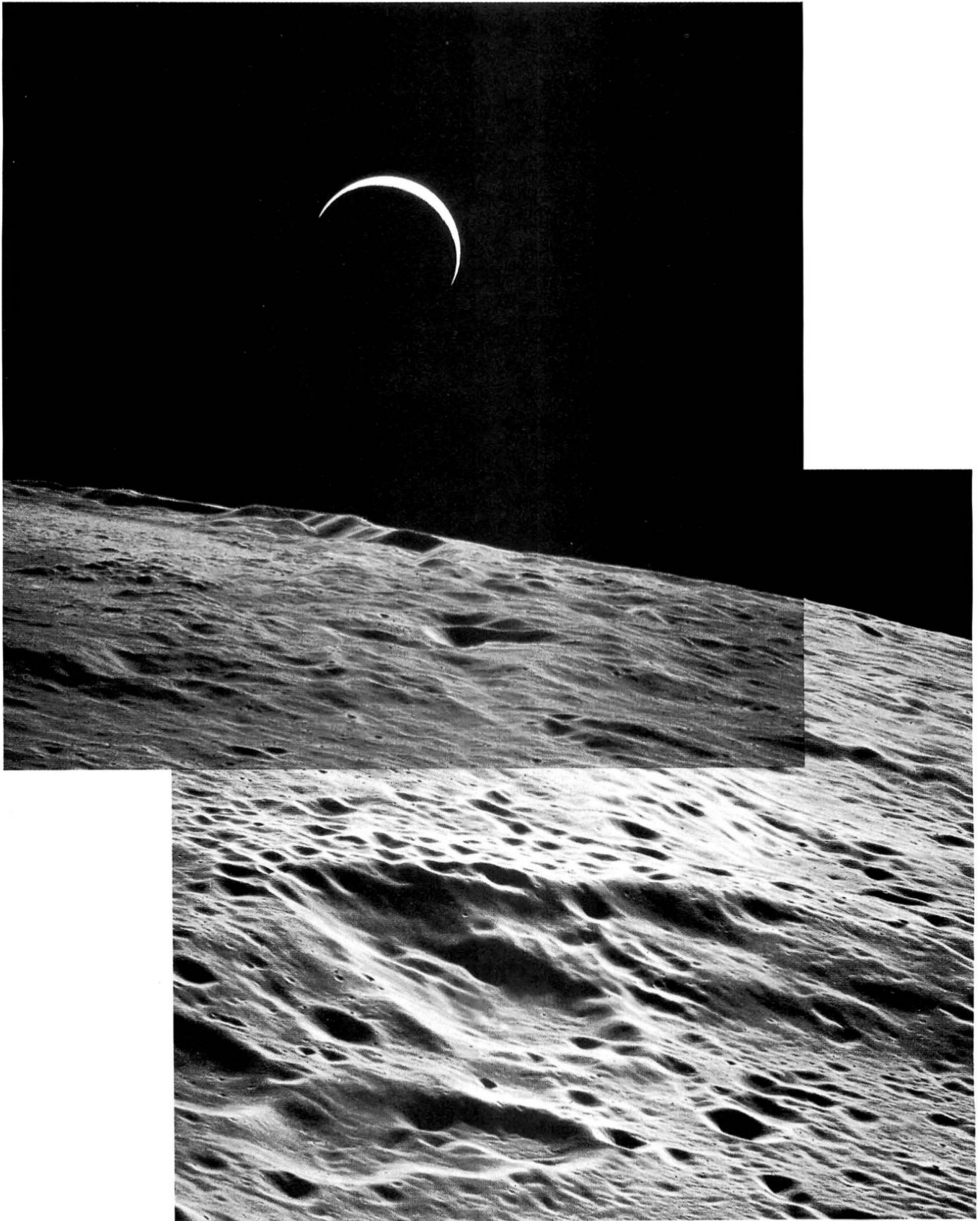
Jim Irwin often tells the story of how, at the end of his last Moonwalk, he found himself with nothing to do for the first time in three long days, so he took a five-minute "vacation," running around the lunar module, leaping over craters and feeling like a kid at recess. Sometimes the astronauts think about the things they left behind on the lunar surface—Alan Bean's lapel pin, a snapshot of Charlie Duke's family, a hammer and falcon feather used by Dave Scott to test Galileo's theory of falling bodies, and their footprints, which will remain virtually unaltered for millennia, subject only to the constant rain of micrometeorites from space.

The command module pilots, who orbited the Moon alone while their

companions explored the surface, came to know the pockmarked world with an intimacy not afforded the Moonwalkers. Theirs was a global view of lava "seas," enormous craters, ridges, mountains. They knew total isolation in the minutes they spent on the lunar far side, out of radio contact with Earth. None confesses anxiety at this separation from humanity—on the contrary, as fighter pilots, they reveled in their solitude. Like the Moonwalkers, they continually raced the clock, struggling to meet all the objectives on their crowded flight plans. And yet, they came home with their own precious memories: Al Worden still recalls flying in total darkness above the far side, looking out at a universe of unimagined splendor.

But it wasn't the Moon or the stars that the astronauts remember as the most stirring sight of all. Rather, it was the Earth, tiny and precious, rising beyond its battered, lifeless satellite.

The Apollo voyagers will tell you that their photographs don't convey the real experience of going to the Moon. In the coming century, new generations of explorers will have to learn that for themselves.



Apollo 15 *A sight to remember: Earthrise, as photographed by command module pilot Al Worden.*

APOLLO 8

Crew: Frank Borman, James A. Lovell, Jr., William A. Anders
Dates: December 21-27, 1968



The first astronauts to ride the huge Saturn 5 booster, Borman, Lovell and Anders also were the first human beings to leave Earth's orbit. Three days later, on Christmas Eve morning, they arrived at the Moon. After a four-minute blast of their spacecraft's engine they entered lunar orbit, circling the Moon ten times in the next 20 hours, taking photographs, making navigational sightings and beaming live TV transmission back to Earth, including a reading from the Book of Genesis. In the first hours of Christmas Day the astronauts left the Moon to head for a fiery re-entry in the Earth's atmosphere and a pre-dawn splashdown in the Pacific.



Photo by William A. Anders

APOLLO 10

Crew: Thomas P. Stafford, John W. Young, Eugene A. Cernan
Dates: May 18-26, 1969
Command Module: Charlie Brown
Lunar Module: Snoopy



After Apollo 9's checkout of the lunar lander in Earth orbit, Stafford, Young and Cernan staged a dress rehearsal for the lunar landing. While Young remained in lunar orbit, Stafford and Cernan descended in Snoopy to within 50,000 feet of the Moon's surface, testing the lander's engines and reconnoitering the landing site chosen for Apollo 11. An anxious moment came when Snoopy's ascent stage gyrated wildly minutes before a scheduled engine firing, but Stafford stabilized the craft and the pair went on to rendezvous with Young. For those watching on Earth, Apollo 10 offered another first: live color television transmission from space.

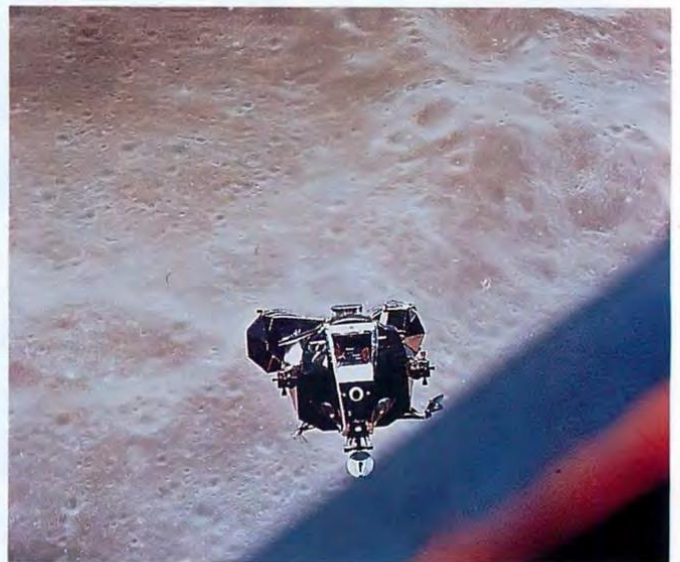


Photo by John W. Young

APOLLO 11

Crew: Neil A. Armstrong, Michael Collins, Edwin E. Aldrin, Jr.
Dates: July 16-24, 1969
Command Module: Columbia
Lunar Module: Eagle



Apollo's culmination, the result of eight years of planning and test flights, came on July 20 at 4:17 p.m., Eastern Daylight Time, when Armstrong and Aldrin touched down on the Moon's Sea of Tranquility while Collins remained in Columbia. More than six hours later, wearing pressurized space suits, Armstrong and Aldrin climbed out of Eagle and spent two and a half hours walking and working on the surface. After a sleepless night inside the lander (the cabin was too bright and too chilly), the men fired Eagle's ascent stage engine to lift off the Moon, 21 hours after they had touched down, and rejoined Collins. The three astronauts returned to Earth with 46 pounds of lunar rocks and soil.

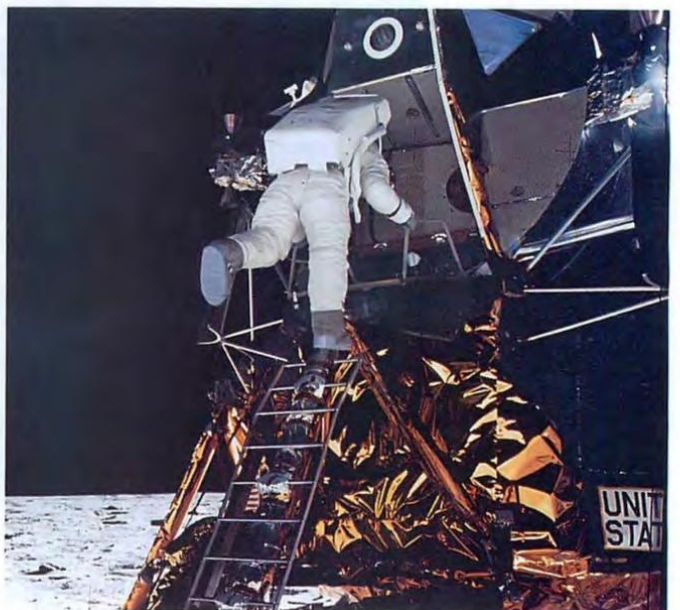


Photo by Neil A. Armstrong

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Art Courtesy of NASA.



L U N A

From Texas to Japan, planners are working to make sure that Apollo's fortieth anniversary is celebrated on the Moon.

By Miles Weiss and Greg Freiherr

It dominates the night sky, taunting those who can see but not touch it. For a short time—41 months, to be exact—the Moon was within our grasp. Then, just as suddenly, it was gone. Now some would have it back again.

During that brief period when the Moon was an inhabited place, NASA envisioned follow-on bases, with six people stationed on the surface for half a year. Their home would have looked more like a water tower than a lunar city. Now, 20 years after the first Apollo landing, ideas for establishing outposts on that nearby world are again bubbling to the surface. Some are primitive, almost Neanderthal: explorers living in caves, lunar villages built in tunnels and caverns. Others border on science fiction: Moonbases sprawling over the lunar surface, shielded from radiation by force fields.

Once again, NASA engineers—and others—are tinkering with ideas for using the Moon as anything from a scientific outpost to a training ground for Mars missions. Much of the technology for a return to the Moon is already in hand, developed for Apollo and Skylab, or for the shuttle and proposed space station.

"The object is to go back to the Moon—not to develop neat new technologies," says Robert Staehle, president of the World Space Foundation in Arcadia, California. "If you go back to the Moon quickly, but in a way that says you intend to stay, the technologies that make it easier and cheaper to get there will come along in due time."

Rather than Americans racing the Soviets, engineers are competing among themselves to come up with plans for re-populating the Moon. Their ideas range from the simple to the complex, the academic to the commercial, the conservative to the devil-may-care.

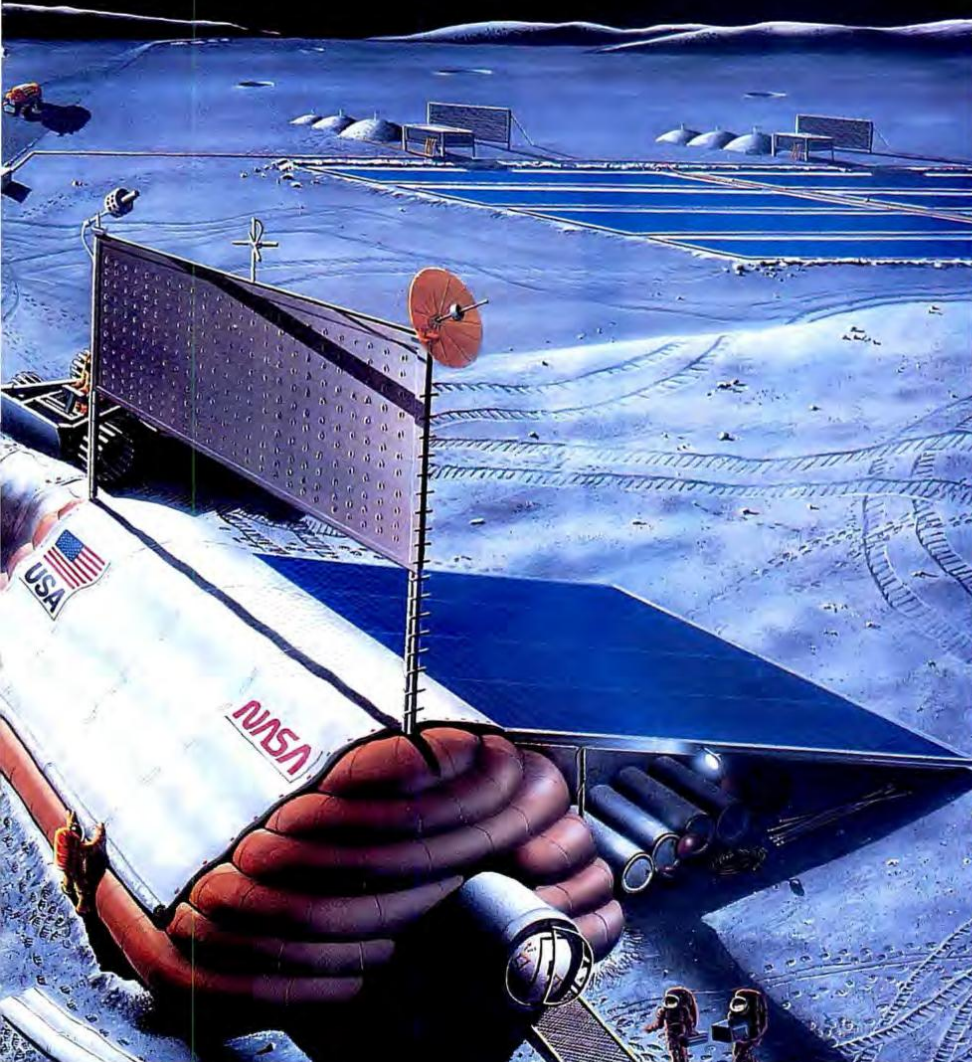


Foremost in everyone's mind is the need to protect future astronauts from the blazing heat and abominable cold of the lunar day and night, as well as from meteors and lethal radiation. One solution would be a kind of extraterrestrial cave dwelling, built inside "lava tubes." These natural tunnels exist in Hawaii, Oregon and other regions on Earth where lava has spewed from volcanoes. Geologists believe that lunar rilles—beds of dried lava that crisscross the Moon's surface—may in fact be collapsed lava tubes. Stronger, sturdier tubes, some of them hundreds of miles long, may be buried intact underneath.

Lava tubes would provide a natural shell for fragile structures built inside them. One idea is to erect a

pressurized tent made from inexpensive plastics. "You could have a series of compartments made of plastic with doors and air locks," explains Fred Horz, a staff scientist in the Solar System Exploration Branch of NASA's Johnson Space Center in Houston. "You could put a whole production plant into the cave—lay out pipes and machinery like in a terrestrial factory."

If lava tubes are nowhere to be found, astronauts might make their equivalents. Conventional explosives, laid below the surface, might hollow out whole caverns. Or automatic tunneling machines sent ahead of the lunar settlers would melt the ground; researchers at Los Alamos National Laboratories in New Mexico are now studying such a tunneling machine, which



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would use a nuclear generator to create heat. Melted lunar material would cool to form a glass surface along the sides of the tunnel, sealing the walls so the entire man-made cave could be pressurized.

For those who'd prefer not to live in Moon caves, there are plenty of ideas for lunar architecture. Modules similar to those proposed for NASA's space station Freedom could even be delivered to the Moon as shelters.

"The guys in accounting love the idea, because it means you can open a space station module assembly line and buy 20 instead of eight, which makes everything cheaper," says Wendell Mendell, chief scientist for lunar base studies at NASA's Johnson Center.

An inflatable dome would be the centerpiece of a lunar outpost powered by huge solar arrays.

But people who are going to live and work on the Moon may not want to live in dwellings built for an orbiting space station. Gravity would make the accommodations inadequate, according to Larry Bell, chairman of the Houston firm Bell and Trotti, and director of the Sasakawa International Center for Space Architecture at the University of Houston. One problem would be the absence of a walkway, since astronauts in Earth orbit would simply float to their stations. Another would be the cramped sleeping quarters: in zero-g you can sleep on the ceiling, but in lunar gravity only the floor is available.

NASA is now in the early stages of redesigning these modules for use on the Moon. Nathan Moore of Johnson's Manned Systems Division has outlined two concepts for a "Hab/Lab" that would be divided into an upper crew level and a lower laboratory level. Installing a central corridor in the split-level module would leave more room for equipment, while a side corridor would make things roomier for the crew.

"The side corridor version is pretty loose on how it uses volume," Moore said. "The other is almost too densely packed. I think the optimum would be somewhere in between."

Other problems with lunar design might not be recognized until the modules were actually put on the Moon. "We know a lot about designing for zero gravity," Bell says, "but we know less about partial gravity."

What is known suggests that lunar bases could revolutionize architectural engineering. "The Moon has a very low gravity compared to Earth, and it is very quiet in terms of seismic activity," says Stewart Johnson, principal engineer for the BDM Corporation in Albuquerque, New Mexico. "So structures can be very lightweight. They would definitely appear flimsy by terrestrial standards."

Perhaps the flimsiest and easiest structure to build would be an inflatable Moonbase. The walls could be made of beta cloth, which is now used in space suits, or Kevlar, the stuff bullet-proof vests are made of. Once on the Moon, astronauts would just blow up their new homes and walk in. Dividing walls, floors and furnishings would add a touch of home. "It would be a more Earth-like environment than a small metal module," says Michael Roberts, an engineer in the Advanced Programs Office at Johnson.

Several designs for lunar "buildings" are being considered. The grandest is a sphere 52 feet in diameter, spanning four stories and providing the same amount of room as 11 space station modules. The sphere, which could house a dozen crew members, would have different facilities on each floor: crew quarters on top; recreational, health and eating facilities on the third; space and surface operations on the second; and mission operations, including laboratories, on the bottom.

continued on page 60



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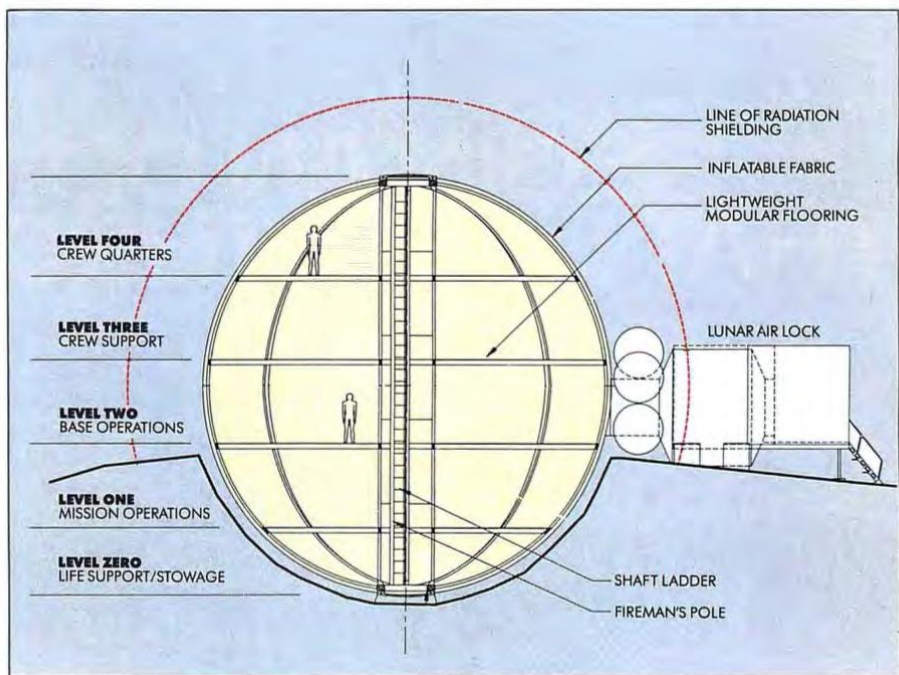
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continued from page 53



The crew would travel between floors using a central "stair well" running the height of the sphere. There would be three exits, including an airlock where pressurized rover vehicles could dock—allowing astronauts to leave the sphere without a spacesuit—and another airlock for lunar shuttles.

"For protection, the base would be set in a crater, either existing or man-made," explains Kriss Kennedy, an aerospace engineer at Johnson. "Coiled around the outside to provide a protective shield would be a sock filled with lunar soil."

Lunar dirt is commonly used in the design of nearly all proposed shelters, even those modified from space station modules. In their case, dirt would be heaped over the top and plowed up along the sides of the module.

But using soil as shielding material is only one way to protect Moon explorers from the harsh lunar radiation and tem-

perature extremes. Some engineers think that our first permanent base on another celestial body should have a little more pizzazz—like a force field to repel dangerous radiation. Magnetic fields are now being used at high-energy research facilities on Earth to guide beams of energetic matter. Their use on the Moon is admittedly a stretch of the imagination, but an intriguing one.

"This is not something that physicists might agree is practical," says Michael Duke, chief of Johnson's Solar System Exploration Division. "But if you are able to build big superconducting magnets and operate them at modest temperatures, you may be able to build shields against the radiation environment on the Moon."

Above: A cross-section of a proposed lunar habitat. Below: An astronomical observatory on the Moon's far side.



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The Magazine of Space Exploration

November/December 1989

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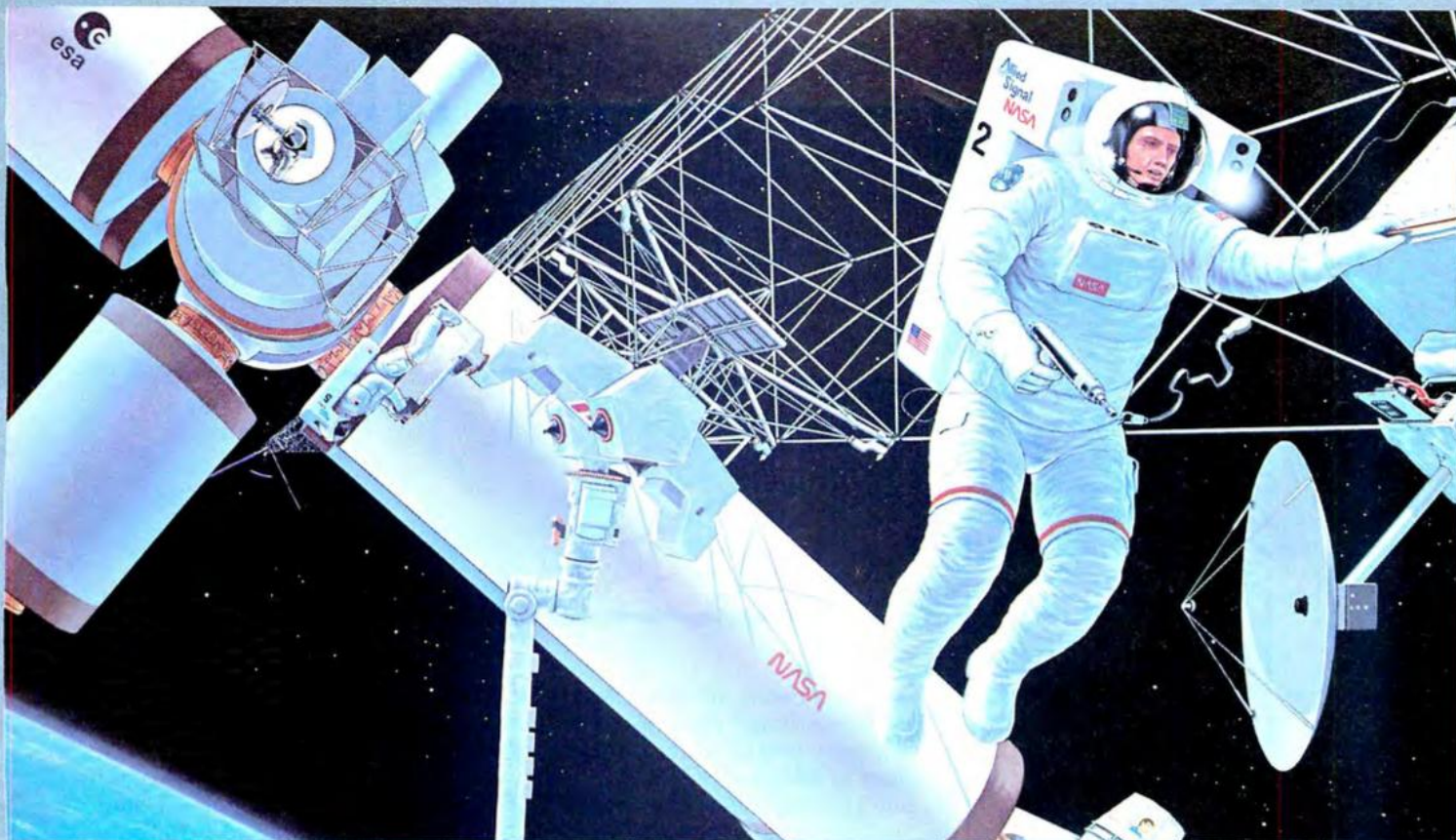
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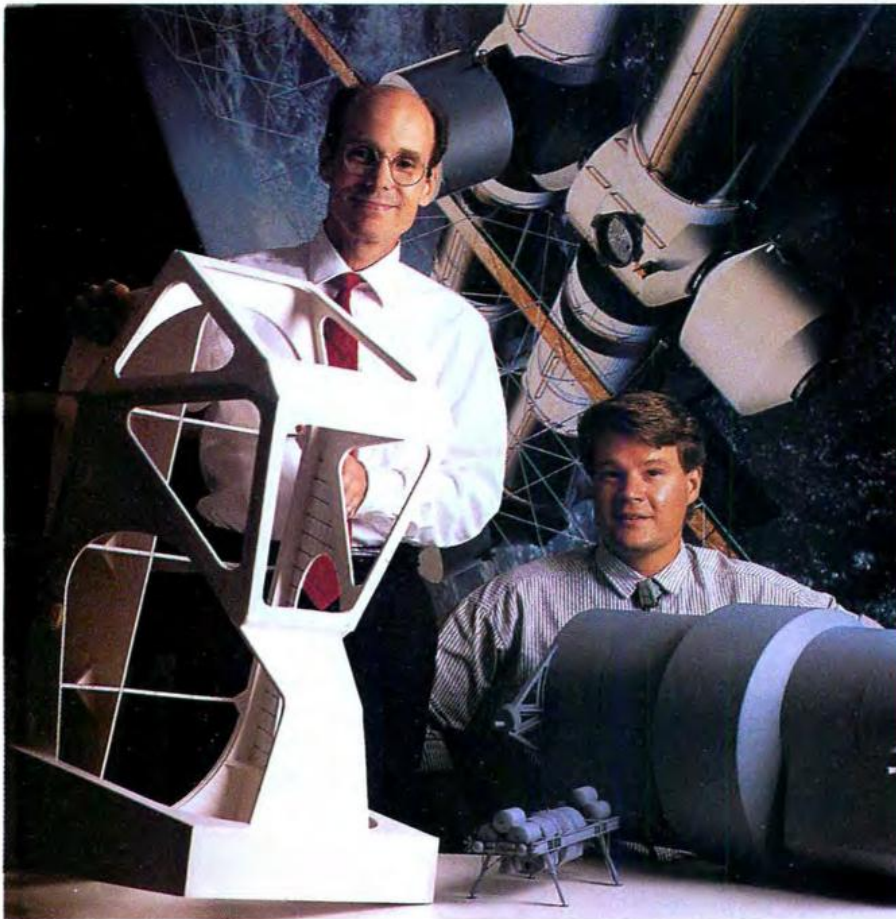
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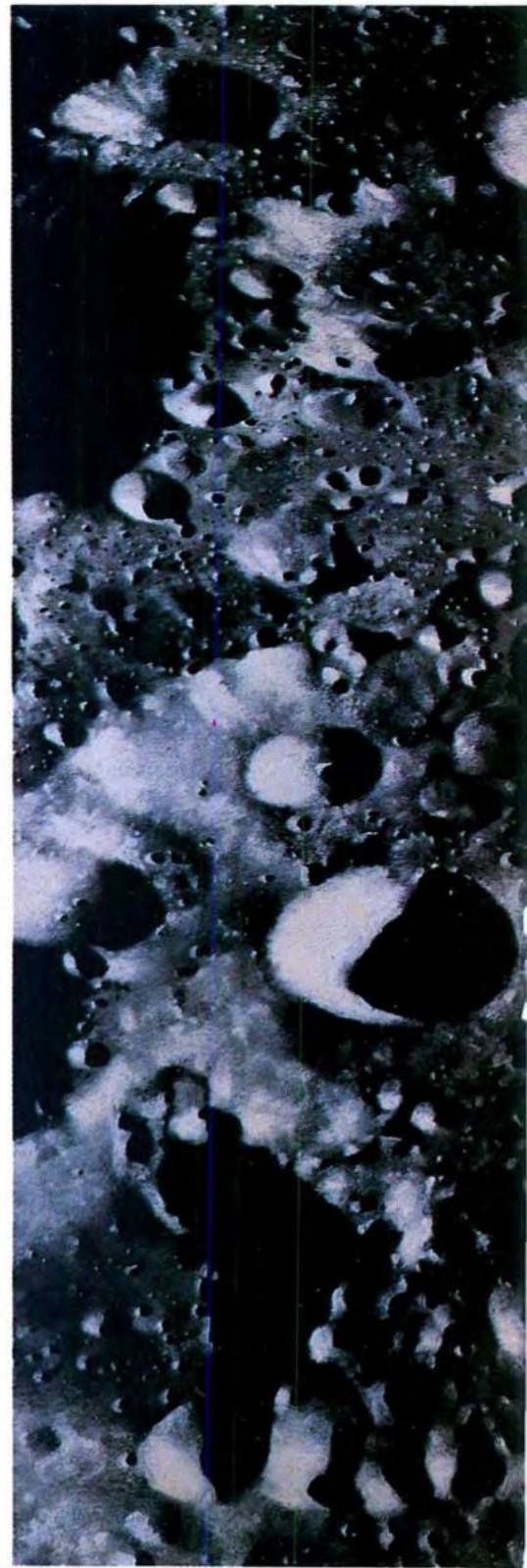
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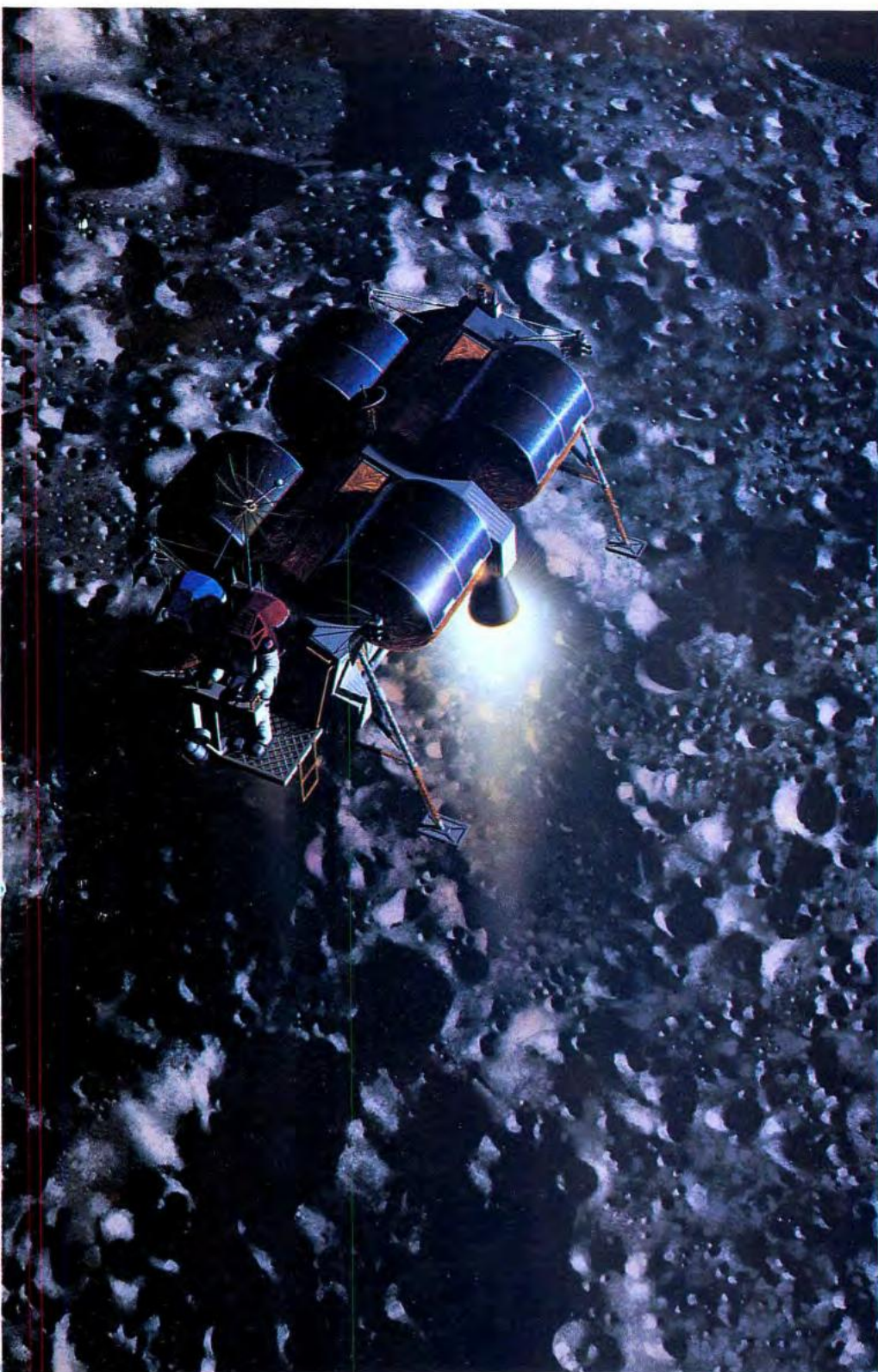
RAYMOND GENDREAU

Griffin (standing) and Hudson in the studio. At right, their Lunar Utility Vehicle.



*One's an artist,
the other's an engineer.
Together they'll show you
pictures of the future.*
BY JEROME RICHARD

The Dream



In the early days of the space shuttle, when NASA was first kicking around the idea of a "Space Flight Participant" program, the categories of people considered most likely to become the first private citizens to orbit the Earth included teachers, writers, TV reporters—and artists. If things had gotten that far, Paul Hudson would have been a leading candidate.

But even before the Challenger accident postponed the program indefinitely, Hudson says he wouldn't have gone. He would love to fly on the shuttle, but thinks the few onboard seats should be allotted to specialists with essential missions, not to spectators.

Anyway, he travels to space almost every day. He does it in his studio, where some of the hardware for future space missions begins in the imaginations of Hudson and his collaborator, aerospace engineer Brand Griffin.

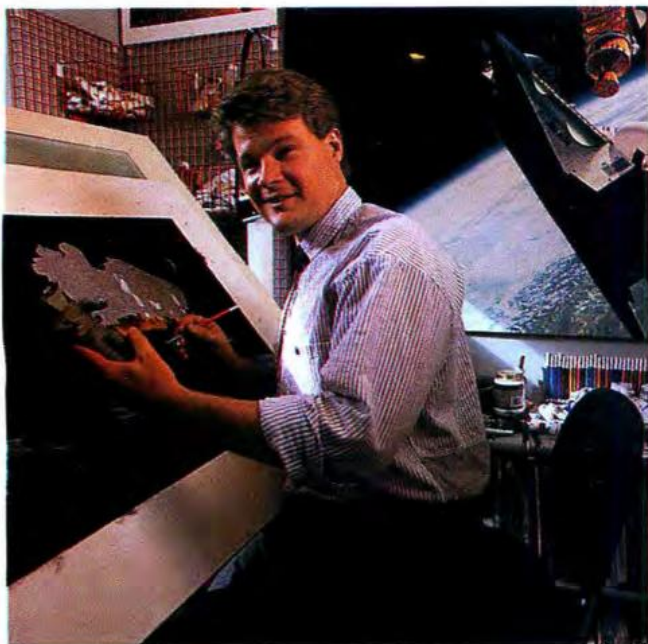
Born in the frontier state of Alaska, the sandy-haired artist has been an enthusiast of space travel since the day he watched the Apollo astronauts take that first small step on the Moon in 1969. He was nine years old then, living in California.

The wonder of that event still shines through the square, boyish good looks of the mature, professional artist Hudson is today. As a child he wanted to be an astronaut, and in high school he started out majoring in science and minoring in art. But as the space program seemed to slow down in the 1970s and the planets remained unexplored, he realized that he "could get to these worlds a lot faster by painting them." He switched his major and minor around, and after graduation enrolled at the Art Center College of Design in Los Angeles.

Hudson's first professional job was at Disney's Epcot Center in Florida, where he designed spacecraft and undersea colonies. After freelancing for a while, he answered Boeing's call to work as an artist depicting the space station designs of a young engineer named Brand Griffin.

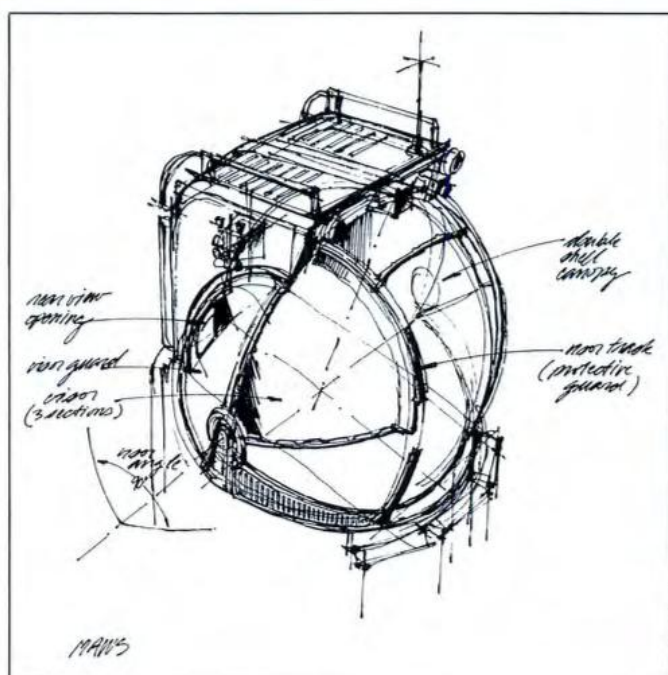
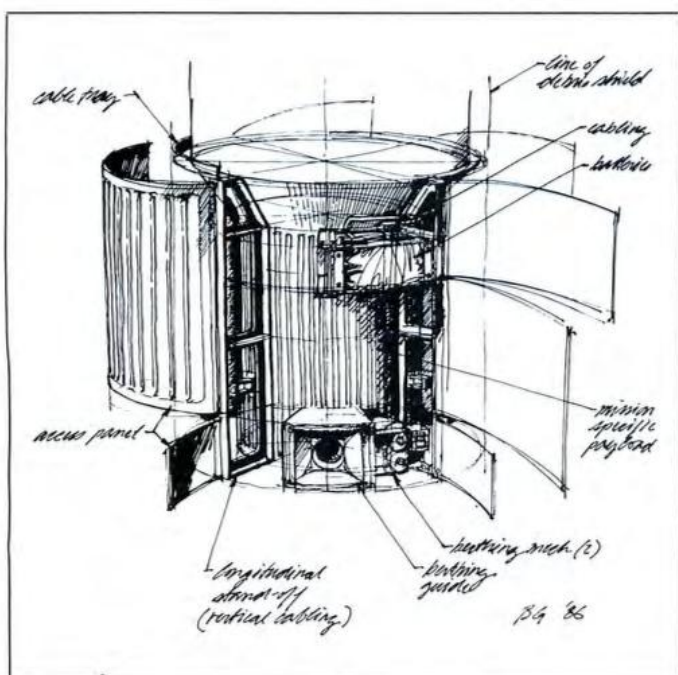
Two years later, the entrepreneurial spirit seized Hudson again, and he returned to freelancing. His work has been commissioned by NASA, *National Geographic*, Time-Life, the President's National Commission on Space and several private corporations. Then last year, he and Griffin teamed up again for a series of paintings of space hardware published as a calendar. A new partnership, called "SpaceWorks," was born.

nTeam



RAYMOND GENDREAU

Hudson (above, at his drawing table) turns Griffin's sketches into finished paintings like this scene of a Manned Autonomous Work Station (MAWS) in the vicinity of a space station. Griffin's attention to detail—how a viewing visor opens, or where a spacecraft's cabling is stowed—comes from his own experience in designing and testing actual space hardware. Lower right: The engineer at work inside a weightlessness simulation tank.



BRAND GRIFFIN



GRIFFIN HUDSON



BOEING AEROSPACE

At first glance, Hudson's pictures appear to be photographs. Then you remind yourself that we haven't yet put a camera on the surface of Neptune, and that it will be years before astronauts skip over the surface of Mars with portable jet packs strapped to their backs. The dramatic realism of Hudson's work is the result of the intensity of his imagination and a devotion to detail he shares with Griffin.

"I want to be on the Moon," Hudson says. "I want to be flying that craft. The only way for me to do that right now is to paint it as realistically as possible."

The paintings usually begin with Griffin's engineering sketches. In his job at Boeing, he directs the design of the habitation modules, or living quarters, for NASA's Space Station Freedom, scheduled for launch in the mid-1990s. Hudson describes his partner as a "driving force" and "a genius." The only problem is that Griffin works in Huntsville, Alabama, and Hudson about 40 miles from Seattle. Hudson says they keep Federal Express in business.

Griffin has architecture degrees from Washington State and Rice University, where his Master's thesis, not surprisingly, was on the design of a space station. He also has extensive knowledge of engineering and human physiology. Griffin manages to be pleasant and intense at the same time. He has won the Prix de Rome study fellowship, as well as three NASA faculty fellowships to work at the Spacecraft Design Division at the Johnson Space Center. A pilot and experienced scuba diver, he believes in personally testing what he designs. He has flown NASA's zero-g aircraft, and has spent many hours in space suits, in the simulated weightlessness of a "neutral buoyancy" tank.

It was Sputnik that first attracted Griffin, 42, to space. He read some science fiction when he was a kid, but, like Hudson, prefers nonfiction. "Nothing," he says, "is more unpredictable than fact."

After working all day designing the space station for Boeing, Griffin goes home and works on the even more advanced projects that Hudson will turn into models and paintings. When they actually get together, they talk about space travel with the knowledge of veterans and the enthusiasm of kids.

Unlike the space hardware dreamed
continued on page 55

FREE POSTER INSIDE! ■ 60 WAYS TO LEAVE THE PLANET

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The Magazine of Space Exploration

May/June 1990

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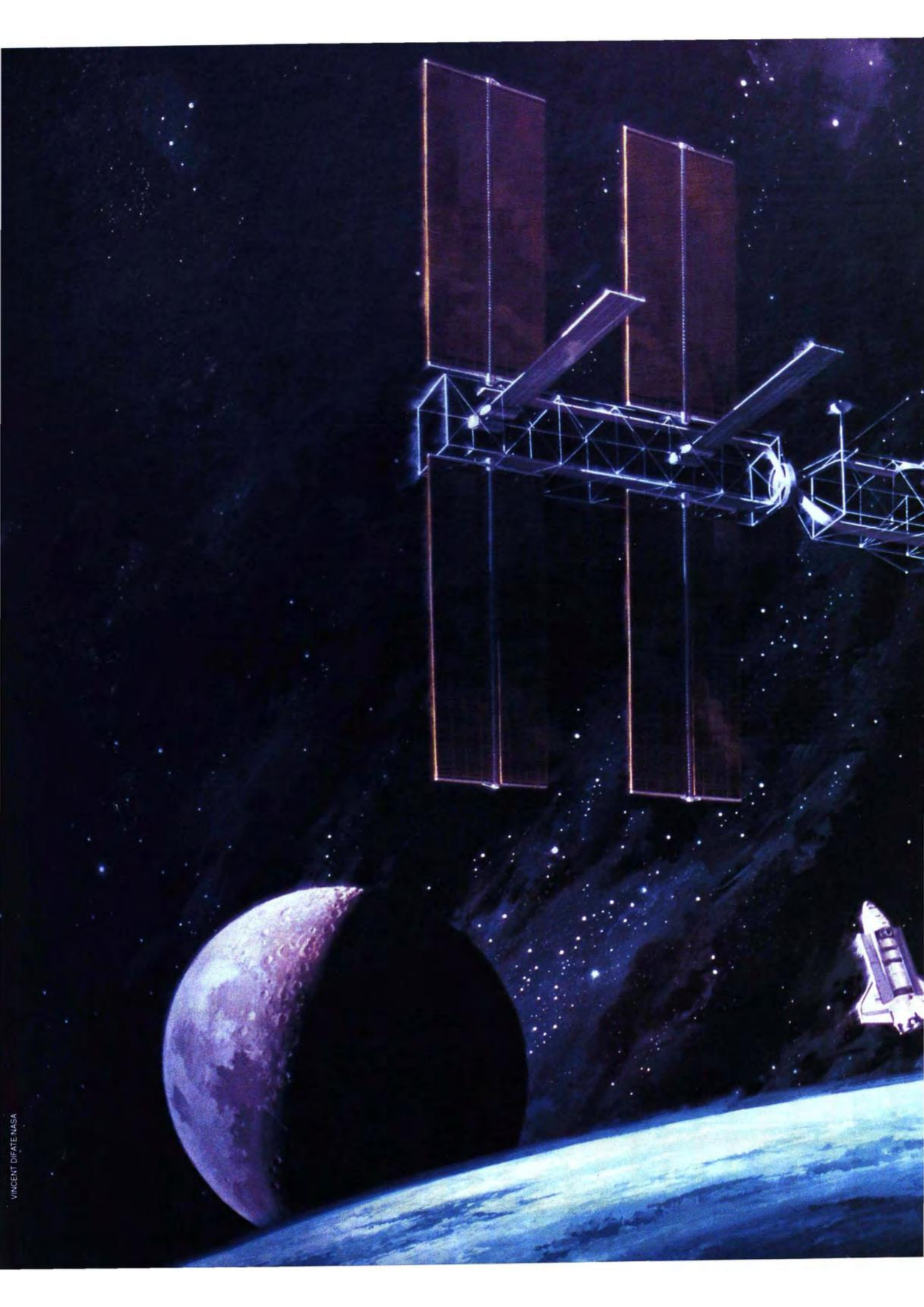
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ONBOARD FREEDOM: PART 2

2000-2010

We've all had the experience. You're on a two-week vacation with a friend, a close friend, but by the eighth day you find yourself at dinner fingering your steak knife and looking longingly at your companion's neck. You may have set out together to enjoy the wonders of Paris, the grandness of Vienna or the crashing waves of the Kona Coast, but now the person you liked so well so recently seems unable to move without making your skin crawl.

As trivial as it may seem, this sort of problem is a major concern for the engineers, scientists and psychologists who are tackling the issues of living and working on space station Freedom. When it comes to operating the station, humans will be the linchpin. If the crew should grow unhappy, frustrated, moody or downright ornery, efficiency will suffer and the ration-

SPACE BASE

Take eight busy people, mix at close quarters for six months at a time, then remove gravity. Welcome to the space station. By Chip Walter

Whatever their duties, all crew members must learn to work in weightlessness. Push too hard off the floor and you could catapult yourself into the ceiling.



Dining in the wardroom: As on Earth, the kitchen table will be a social hub.

ale for maintaining a permanent orbiting base will begin to look less than sensible — especially at a cost of some \$30,000 per hour per crew member!

Once you accept the basic concept that human beings will work, sleep, play, socialize, exercise, wash and dress while floating around in four truck-trailer-sized cylinders, you realize how much thought must be given to keeping the crew on-board Freedom from going batty in the process. The station will be the space-age equivalent of living on a desert island. When you add the bald danger of the undertaking, the length of duty (three to six months) and the difficulty of designing a weightless environment where up and down are pretty much meaningless, you

begin to appreciate what the folks at NASA call “design challenges.”

Though space stations hardly clutter the Solar System, we do have examples of what can happen when people are forced to endure dangerous or cramped situations for lengthy periods. Thanks to their Salyut and Mir space stations, Soviet cosmonauts have much more experience in long-duration flight than do American astronauts, and they know how bad such confinement can get. “We had prepared for this long and hard together, rehearsing every anticipated problem,” wrote Valery Ryumin in his diary as he began a 175-day tour aboard Salyut. “But this was done in an environment of other people. Here we

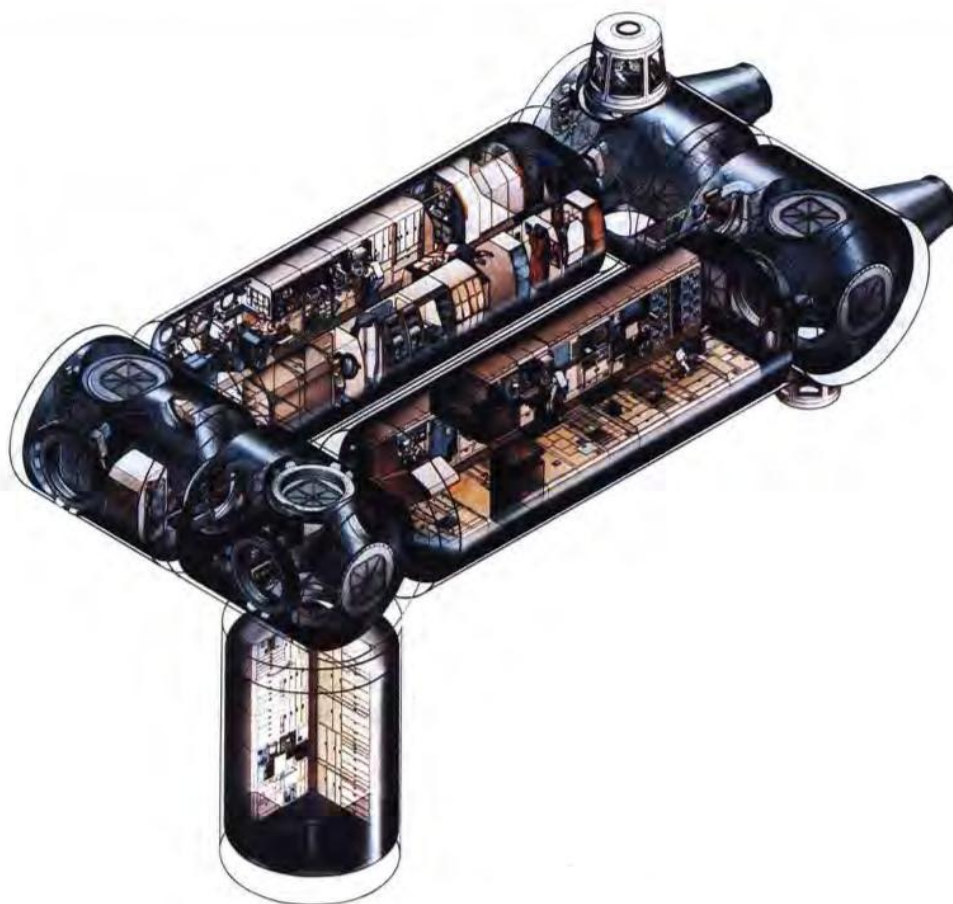
are totally alone. Each uttered word assumes added importance. One must bear in mind — constantly — the other’s good and bad sides, anticipate his thinking, the ramifications of a wrong utterance blown out of proportion.”

What few studies exist on the subject indicate these conditions can damage both social harmony and work performance. An endless list of chores and problems can complicate matters, including food preparation, cleaning clothes, injury and sickness. How will the Freedom crew respond to these challenges of life in zero-g? And what about entertainment, relaxation, personal space, communication with family and friends — or, more precisely, the lack thereof?

Imagine you’re one of four members of a fresh space-station team arriving from Earth. Fittingly, it’s the year 2001 and Freedom has reached what the acronym lovers call AC (Assembly Complete). Every 90 days (and then eventually every 180 days) four crew members will rotate out of the station and return home to be replaced with four new astronauts — in this case you and your team members. This ensures there will always be four veterans on the station. It also will help keep the mix of people relatively fresh.

It has taken two days since launch for the shuttle to rendezvous with Freedom. In the orbital equivalent of parallel parking, the shuttle commander maneuvers the spacecraft within reach of the station’s Mobile Servicing System (MSS) — a trolley-like device that can position various robotic arms wherever needed along the station’s structure. A large docking arm grabs the shuttle gently, to avoid shaking the sensitive microgravity experiments underway inside the station’s three laboratory modules.

Below, clouds swirl and the planet spins



BOEING AEROSPACE

as you gather your belongings and review your checklists with the team members you've been training with for a year now (all told, your mission has been in the planning for some five years). Next you board the station, which, after several days in the steamer-trunk confines of the shuttle's mid-deck, will seem palatial.

Entering through the station's starboard node (nodes are the connecting areas between the main compartments) you'll swim slightly to your left into the habitation module. Here and most everywhere else, Freedom's decor will be — there's no other way to put it — institutional: Whites and grays, fluorescent lighting, lightweight alloys and plastic will predominate. Forty-two feet long and crammed with an impressive array of electronics, the habitation module is a model of efficient packaging, further enhanced by the lack of gravity, which makes every inch of space useable and accessible.

The bottom half of the module will

A sketch of the U.S. modules and connecting "nodes." The design allows various areas to be sealed off in the event of an accident.

tend to be shaded darker than the top half, a subtle reminder of "up" and "down." The entire station will be designed with this orientation in mind. Though having breakfast on the "ceiling" might be novel, (and easily done in orbit) lacking at least a *sense* of up and down can be annoying and confusing — a complaint lodged loud and clear by several former Skylab astronauts who are now working as consultants to the Freedom project.

Your arrival marks an event worthy of celebration as members of the onboard crew gather round the wardroom table in the galley to hear the latest on earthly issues and swap a few good ol' space-age lies. No booze (unlike the Soviets who share a little brandy on similar occasions), but plenty of presents, videotapes and

personal mail for the crew members who won't be departing. Like their Russian counterparts on Mir, the American, European and Japanese astronauts on Freedom will undoubtedly find these small gifts to be so many surrogate hugs and kisses from friends and relatives on the ground.

The habitation module is divided into three major sections: the galley area at one end, the crew quarters at the other, and a bath, toilet and small medical facility forming a "buffer" zone in the center.

The plans for these areas have been badly eroded by budget cuts on Capitol Hill, but designers are working to preserve as many creature comforts as possible. "The human factors of the space station are important," says space station systems manager Phillip Mongan at NASA's Johnson Space Center in Houston. "What we do is to make the everyday things — the meals, the showers, the tools, the liv-

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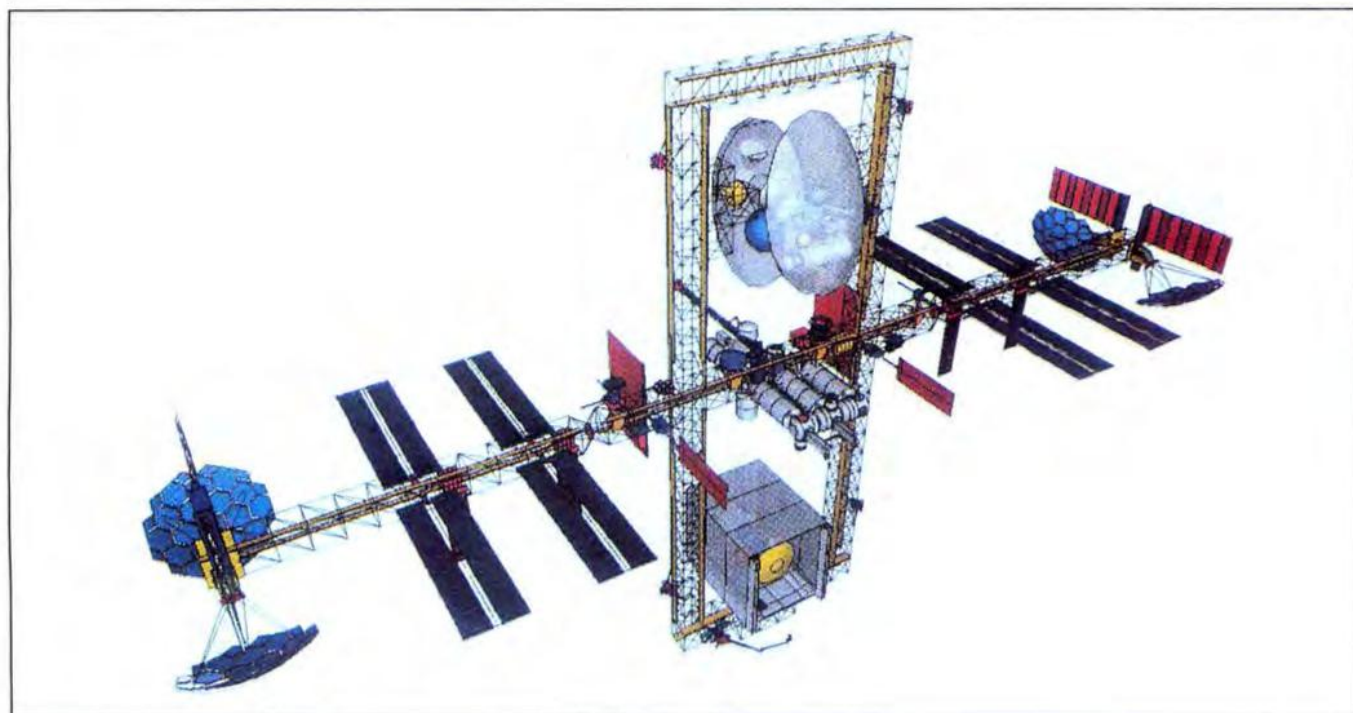
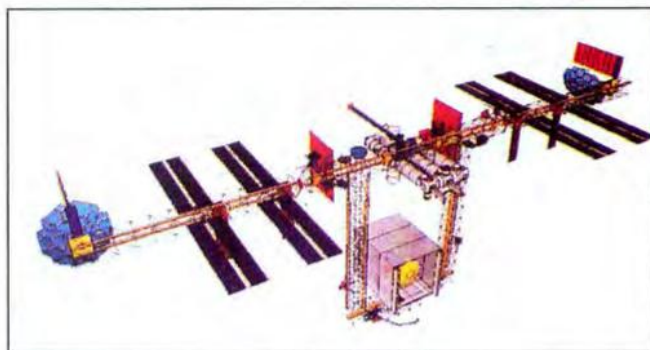
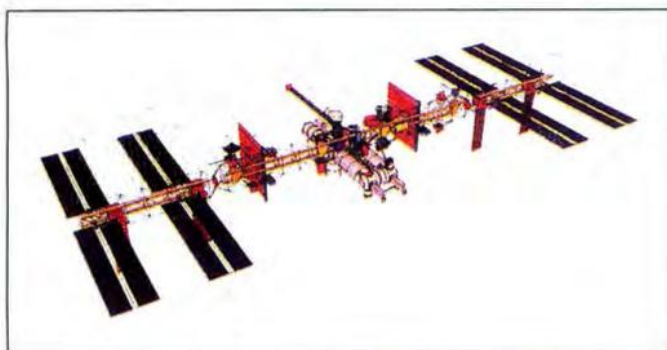


HEAVENS' GATE

An expanded space station may be the harbor from which explorers depart for the Moon and Mars.

The year: 2015. The press and the rest of the world have already seen the four international crew members leave Earth for the aging ramparts of space station Freedom. Now, after several days of additional preparation, they've taken their places in the crew module of their interplanetary vessel. There is a drama in the countdown that the simple recitation of numbers belies. Slowly, in the utter silence of space, the huge arm of the remote manipulator disengages their titanic space ship from Freedom's assembly hangar and sets it adrift. For a moment, there's time for each crew member to wonder how he or she will handle the longest journey any human has ever made. ■ From where they sit, cradled amid tanks, cargo and the leviathan aerobrakes that will bring them skidding to a fiery halt on the edge of a distant atmosphere, they cannot see their destination; but they've gazed upon it often from the portholes of the space station—a tiny, unwinking, red beacon in an infinite sea of stars: Mars, more than 35 million miles away. ■ With the ship now clear of the station, the pilot uses tiny doses of rocket fuel to move the craft into position for takeoff. Then, with Earth spinning below, Freedom a safe distance behind, and the Moon, bright and full, bearing lunatic witness, the ship's enormous engines fire. Like a single Roman candle in the night, the 730-ton ship roars out of Earth orbit, and the first humans to visit another world are on their way.

By Chip Walter



If a spaceship ever actually begins this journey, it will mark the culmination of a dream held by many of rocketry's great pioneers. Hermann Oberth, Robert Goddard and, of course, Wernher von Braun all wondered about such a voyage.

Von Braun was the most recent of the dreamers. He wrote in great detail about the human exploration of Mars, and he always stated his case boldly and dramatically. He was the Cecil B. De Mille of scientists, a Wagner among engineers, and as early as the 1940s he envisioned launching a flotilla of 10 rockets to the Red Planet "manned by not less than 70 men." (His vision failed to predict the likes of Sally Ride.)

The centerpiece of this expedition was to be a wheel-shaped space station orbiting Earth. Here he foresaw an army of workers assembling the spaceport that would launch the first humans to Mars.

Early in the next century, Freedom will grow from a single-keel orbiting laboratory (top left) to a busy Moon-and Mars-port. A bay for lunar vehicles (top right) will be added first.

By the time the Mars vehicle with its large, shell-like aerobrakes (above) arrives, "solar dynamic" dishes at each end of the station will be providing additional power.

His plans for a flotilla and 70 men fell a little wide of the mark, but von Braun hit the nail on the head when he foresaw the need for a space station that would act as a harbor for departing voyagers.

Forty years after von Braun's ruminations, it appears that some version of his dream may yet come to be. Until recently the United States seemed plagued by an epidemic of space exploration options. In

the wake of Challenger, reports stacked up on desks in Washington while scientists and engineers and politicians clamored for everything from a flag-planting mission to Mars to a relatively staid (unless you're an astronomer) Antarctic-like science station on the Moon.

Then last July President Bush finally laid out the administration's plans for America's future in space: take the beast by the horns, first by returning to the Moon ("this time, back to stay"), then by mounting a human mission to Mars and establishing a permanent colony there. The speech didn't take long, but its implications are both staggering and heartening to anyone interested in the long-term future of space station Freedom.

Prior to this announcement, Freedom's fate beyond the completion of its first phase as an orbiting laboratory had remained lodged firmly in neutral. But a plan call-

The Best-Laid Plans

Following President Bush's call last summer for bases on the Moon and Mars, NASA engineers quickly developed five possible plans for achieving those goals. These "reference approaches" range from the simple to the complex. Predictably, the plan with the most stretched-out timetable has since emerged as the favorite, and is the basis for all the dates used here. But there are other proposed scenarios, both within the space agency and outside it.

Anyone who follows the fortunes of NASA knows that politics, economics and the unpredictability of high technology make only one thing certain in the space business: *nothing* is for sure. With that in mind (and short of the entire project being scuttled) here are some of the more important changes that could affect whether, when and how Freedom becomes a space port.

IF	THEN
Political support and funds are lacking...	Keep moving all the dates back, and back, and...
The Soviet Union should join the United States' other international partners in Freedom's expansion...	Its most impressive contribution could be Energia—the heavy launch vehicle that the United States so sorely lacks. Energia is a real rocket, not a CAD/CAM engineer's dream, and it can already tote 220,000 pounds into low Earth orbit. The Mir space station could also become a welcome addition to the effort.
NASA engineers cannot prove that their new design will avoid disrupting Freedom's sensitive microgravity experiments (which are very important to certain U.S. interests as well as to Japan and Europe)...	A separate unmanned station could be constructed exclusively for assembling and servicing lunar and Mars-bound spacecraft. This would blow a Jupiter-sized hole in NASA's schedule for establishing bases on the Moon and Mars.
The deleterious medical effects of weightlessness cannot be managed, at least in the short term...	Engineers may have to consider a Mars vehicle that creates its own artificial gravity, perhaps with a tethered, rotating habitation module.
Public sentiment changes <i>and</i> NASA can successfully argue the case...	The first ships bound for Mars could be nuclear-powered. The technology exists now, and nuclear ships would reach Mars in close to half the time (while solving some tough logistical problems—supplies and the effects of weightlessness among them).
Fast nuclear-powered ships are out, and "closed environmental systems" that recycle water and air and allow the cultivation of edible crops in weightlessness aren't developed on Freedom beforehand...	The space program must resign itself to 300-day trips to Mars—and to the fact that inhabited bases on the Moon and the Red Planet may simply be impossible in the immediate future. Napoleon thought his supply line from France to the Russian front was long. Try the 35 million miles between Earth and Mars.
Congress becomes concerned about the danger to astronauts working in space...	Freedom's expansion could be considerably delayed as a protective hangar is constructed during the expansion's first phase (rather than the second), <i>and</i> as engineers work to develop more sophisticated robots that can perform many of the chores now considered too complex for machines to accomplish.

ing for the colonization of the Moon and Mars created an instant need for an orbiting port—a way station and launch point for the spacecraft that will supply and people those distant settlements.

If the president's goals are to be transformed into realities, NASA believes that Freedom, like von Braun's station, will have to become the hub of the new Space Exploration Initiative (SEI to acronym-mongers). But before it ever reaches its final configuration, engineers will face a morass of chilling, and exciting, challenges; changes that will make the construction of the original station—no mean accomplishment in itself—seem like the smallest of engineering potatoes.

Before a Mars-bound craft departs Earth orbit, Freedom will have to undergo a four-phase conversion that will see it transform from a relatively simple orbiting laboratory to a full-blown spaceport. True, it will never become the gleaming, spinning wheel of Stanley Kubrick's *2001: A Space Odyssey*. But it will change enormously, roughly doubling in size as it's outfitted to construct, repair and launch the first reusable interplanetary spacecraft: ships like no others before them, with aerobrakes the size of skating rinks, elaborate living systems and house-sized fuel and cargo holds.

To accomplish this, 12 permanent crew members and a growing rookery of robots will labor high above Earth for more than a decade. Freedom will become the testing ground for tackling the many problems of interplanetary travel and colonization. Crew members on the station will be as scrutinized as a warren of white laboratory rats, to see how they handle the psychological and medical stresses of life in space. Technicians will try out new methods for recycling water, air and food. Samples of Martian rock and dirt, gathered by roving robots, will be returned to the station for study.

How will all this take place? Given the green light from the White House (but

continued on page 54

SPACE CIRCUS ■ MISSION TO THE SUN ■ WHO'S BEHIND
NASA'S ET SEARCH? ■ DESPERATELY SEEKING PLANET X

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The Magazine of Space Exploration

September/October 1990

Mars

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**THE SHUTTLE: WHY IS IT SO TOUGH
TO KEEP FLYING? page 42**

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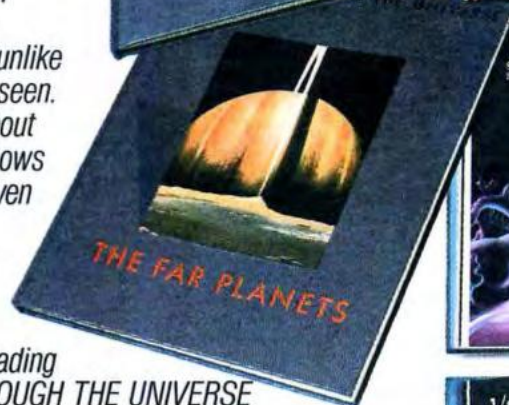
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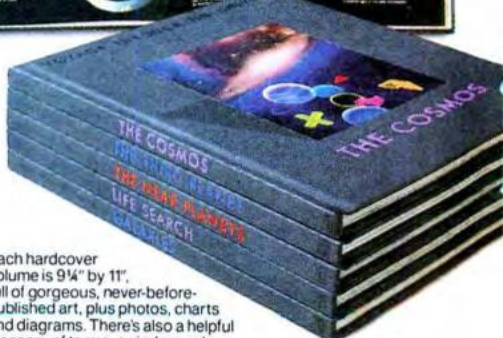
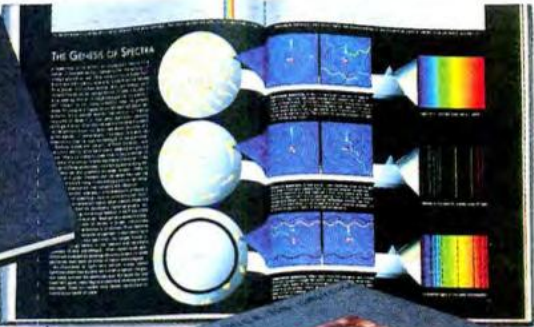
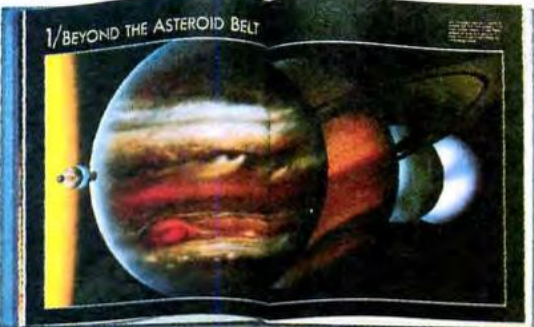
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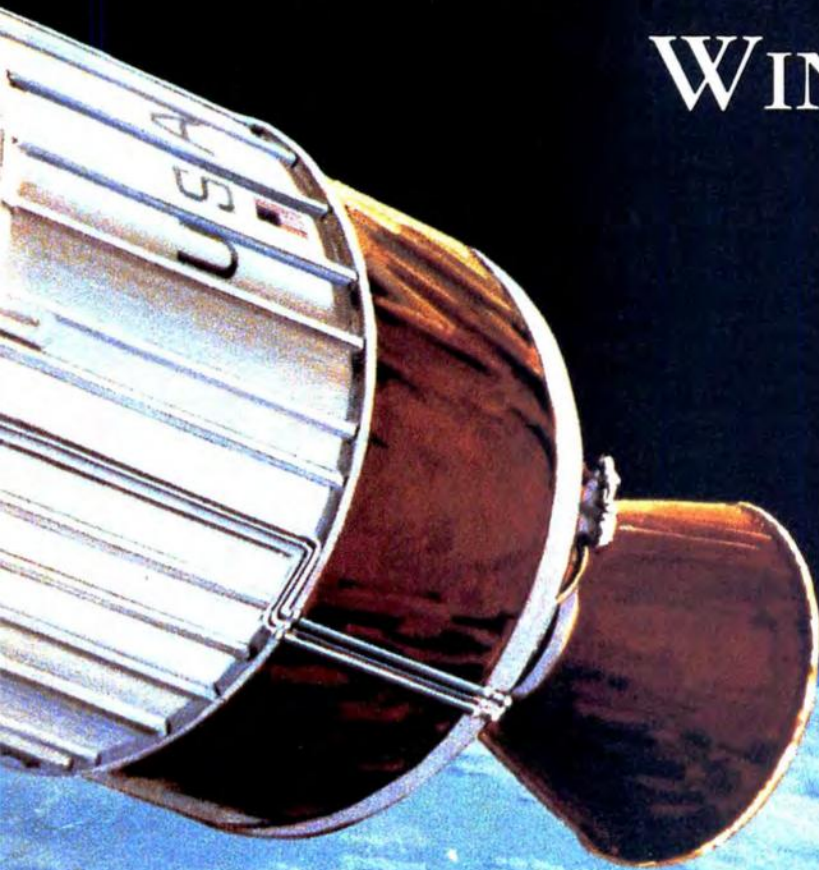


ULYSSES

THE LONG AND WINDING ROAD

It's taken years to get there,
but this international project
is finally about to have its day
in the Sun.

By Nicholas Booth



EUROPEAN SPACE AGENCY

T

his October, the fastest manmade object ever sent into space will be sprung from the cargo bay of space shuttle Discovery to begin a

unique, five-year journey of exploration. What the Ulysses probe seeks is not a new world but a new vantage point; its mission is to give scientists their first look at the polar regions of the Sun.

Like the hero for whom it's named, the European/American project has been beset by so many problems that its story takes on epic proportions: Cost overruns, international disputes and countless delays have given way in recent months to legal challenges by protestors who oppose the spacecraft's use of a nuclear-powered battery.

The fact that Ulysses exists at all is a triumph in the face of adversity.

Ask Derek Eaton, the man most people cite as the mission's motivating force, and the only one who has remained with the project since its inception. The British-born project manager for the European Space Agency (ESA) has spent more than 15 years of his career devoted to Ulysses. He bears the mien of someone who has learned the value and virtue of patience. "The main lesson I've learned," he says today, "is that there's no such thing as guarantees. Space is a risky business—you have to accept that."

Looking back on those years, Ulysses seems a case history in how *not* to organize an international project. The notion of an international "solar polar" mission had its beginnings in 1974, when the European Space Research Organization (ESA's forerunner) discussed the idea with NASA. The scientific rationale was straightforward enough. Despite the Sun's proximity, scientists are wholly ignorant of many aspects of our neighboring star because we have a limited view of it. Our observations of the Sun are limited to within 10 degrees of the "ecliptic" plane in which the planets orbit.

"It's like trying to study the weather if you could only make measurements near the equator," says Edward Smith, the Ulysses project scientist at NASA's Jet Propulsion Laboratory (JPL) in Pasadena.

Spacecraft have shown that the Sun's influence extends across the whole Solar System in the form of the solar wind, a

plasma made up of superheated electrons, protons, heavier ions and nuclei emitted from the Sun's outer atmosphere. "The Sun's outer atmosphere is an extended region beyond the Sun, continually blowing out into the Solar System," says Smith.

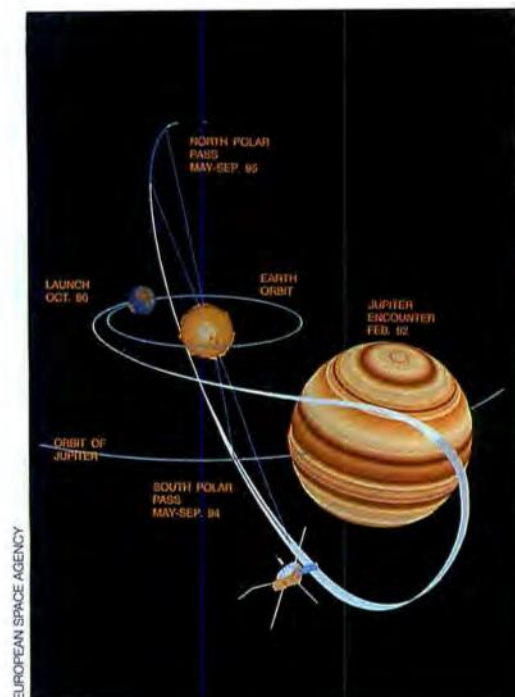
Even our view of this solar wind is complicated by our position. Because the wind is electrically charged, the Sun's extensive magnetic field causes the plasma to rotate with it. As a result, the solar wind is sprayed out like water from a garden sprinkler, trapped by the Sun's magnetic field lines into a spiral pattern.

To improve our view of these complicated dynamics, the International Solar Polar Mission (ISPM) was proposed. Plans called for two near-identical ISPM spacecraft to be launched in 1983. One, supplied by NASA, would pass over the Sun's north pole at the same time as a second ESA probe would round the south pole.

But cost overruns with the space shuttle and the knife-wielding propensity of David Stockman ensured that this happy state of collaboration soon was shattered. The way in which NASA pulled out of the deal still rankles some European project people, who tell apocryphal versions of the story in bars or under cover of darkness. Neither ESA nor NASA officials will be drawn into the fray, but what happened was something like this: Early in 1981, the Administrator of NASA telephoned the Director General of ESA to say, in effect: "The budget mark-up is in, and it's bad news, I'm afraid. We're going to have to cancel our half of ISPM. We're holding a press conference in an hour."

And that was it. One NASA manager reflects: "Unilateral decisions and collaborative projects don't really mix. We had absolutely no idea what we were letting ourselves in for." The launch date slipped to 1986, and the project was cut in half—NASA would now provide the launch for a single European spacecraft, would help with navigation, and would provide tracking with its Deep Space Network.

Still miffed, European managers scored a minor victory three years later by unilaterally renaming the project. A number of ESA people had always hated the NASA title of "Solar Polar," which Eaton would say is better suited to an ice cream. An informal competition to rename the craft led Professor Bruno Bertotti of the Uni-



First stop, Jupiter: A gravitational assist from the giant planet will swing Ulysses out of the ecliptic plane in 1992.

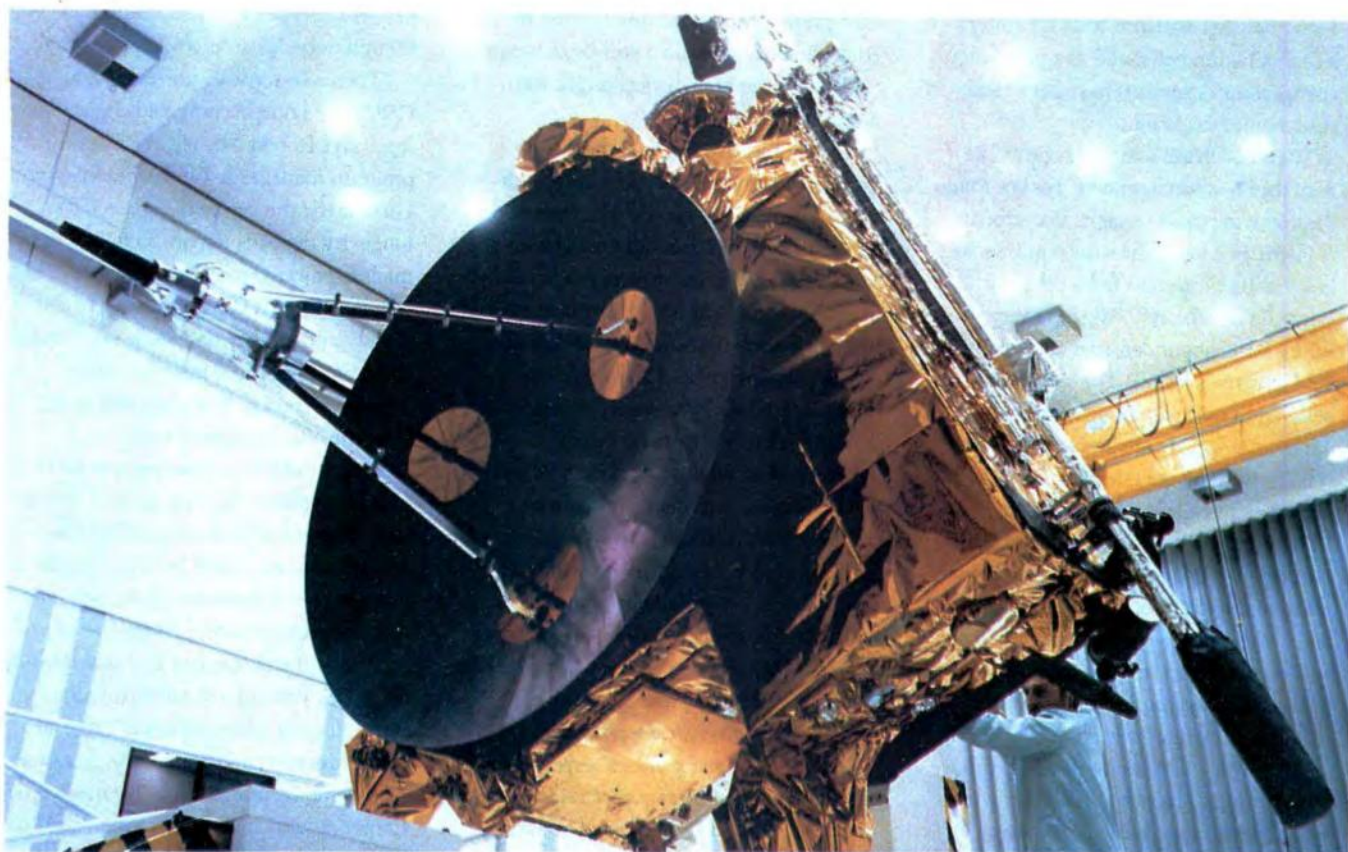
versity of Pavia to propose "Ulysses."

"As the whole project had become a bit of an odyssey, it seemed apt," an ESA scientist says. The name was duly announced to the press in Europe before NASA could weigh in with its own candidate, and Ulysses it became.

Since that nadir in the early 1980s, relations between the two agencies have improved. "We realize that the European system works differently—not better, just different," says JPL project official Ed Massey. Derek Eaton, too, seems more tractable. "I've been critical of NASA in the past. But those criticisms are the sorts you'd reserve for any bureaucracy."

When the Challenger accident delayed the planned 1986 launch yet again, Ulysses was rescheduled for this October. Eaton's single-mindedness has ensured that the spacecraft will be ready despite its many journeys through Europe, out to Cape Canaveral, back to Europe and back to the Cape again.

The spacecraft carries nine experiments fixed to its main body and mounted on long "booms." All are the products of collaborative efforts. "Space scientists are getting better than industry at putting consortia together to get [experiments] on a spacecraft," Eaton reflects.



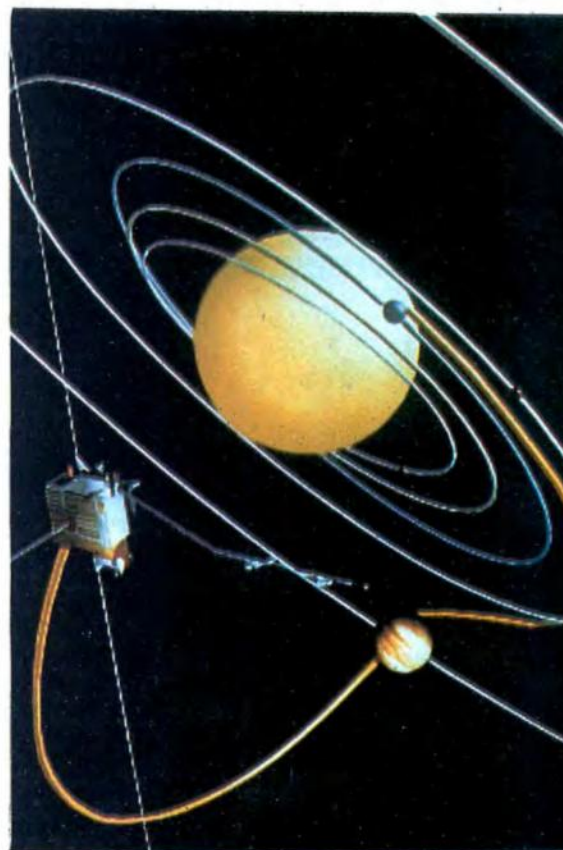
EUROPEAN SPACE AGENCY

Six hours after the shuttle reaches orbit, Ulysses will be released from Discovery's cargo bay to fire two separate solid-fueled boosters, one after the other. (The choice of upper stages has been an odyssey in itself, with no fewer than three changes to the original project plan. When a proposed Shuttle-Centaur upper stage was scrapped after the Challenger accident, the dual-booster scheme was devised for Ulysses.)

Once free of the shuttle, the spacecraft will speed outward to Jupiter so that it can use the planet's immense gravitational energy to pick up the velocity needed to head out of the ecliptic plane. Traveling at better than nine miles per second, Ulysses will reach Jupiter in only 16 months. The criticality of its trajectory cannot be overstressed: Its aim point at Jupiter is a moving target some 100 miles wide and nearly 500 million miles away. Hurtling over the planet's north pole, the spacecraft will be propelled downward to pass under the south pole of the Sun in May 1994. By the time it comes "half circle" over the Sun's north pole in May 1995, nearly five years will have elapsed since launch.

In this regard, NASA's ability is pre-eminent: JPL navigation engineers have perfected such games of cosmic billiards with the Voyagers and Pioneers.

Data from instruments mounted to the spacecraft will be relayed back to Earth by a large-dish antenna (above). Right: the probe will pass under the Sun's south pole in mid-1994, then up and over the north pole a year later.



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Lunar Flash Doesn't Pan Out

FOR THE PAST TWO MONTHS, IMPACT AFICIONADOS have been abuzz over the apparent confirmation that a house-size object struck the Moon on November 15, 1953, leaving a crater. The bright flare captured that evening by Leon H. Stuart's backyard telescope appeared to match the position of a small, bright splash of ejecta recorded by a spacecraft four decades later. Bonnie J. Buratti (Jet Propulsion Laboratory) and Lane Johnson, a student at Pomona College, unearthed this 1½-kilometer-wide "smoking gun" in data from the Clementine orbiter, whose high-definition cameras mapped the entire Moon in 1994.

Although the annals of amateur astronomy chronicle hundreds of transient lunar phenomena — almost all considered highly suspect — Stuart's event stands apart because it was both seen and photographed (May issue, page 24). That fact, together with the Clementine evidence, allowed Buratti and Johnson to make a strong case in January's issue of the scientific journal *Icarus*. A NASA press release even trumpeted, "NASA Solves Half-Century-Old Moon Mystery."

But a little more historical digging would have shown that the "new" crater is not new at all. John E. Westfall (Association of Lunar and Planetary Observers) has discovered that the bright blip seen by Clementine also appears in telescopic plates taken decades before

Stuart snapped his controversial exposure. In particular, Westfall notes, the feature is "pretty obvious" in a photograph made with Mount Wilson's 100-inch Hooker telescope in 1919. It also turned up on a plate taken in 1937 with the 36-inch refractor at Lick Observatory. Westfall has submitted his analysis to *Icarus*.

In their paper, Buratti and Johnson mistakenly suggest that the resolution limit of ground-based efforts is about 4 km (2 arcseconds) and thus that the candidate crater itself must be far too small to have been photographed. They did examine a few telescopic images for a small crater at the impact's presumed coordinates but found nothing. A search of Lunar Orbiter frames, taken during the 1960s, initially turned up empty but later did reveal a 500-meter pit.

Even before Westfall came forward, doubts had been growing about the Stuart-Clementine connection. For one thing, Stuart reported that the bright flare lasted at least 8 seconds, an implausibly long fireball for so small a crater. "We now know that an event of that scale should last no longer than a second, but [Stuart] didn't," comments impact specialist Alan W. Harris (Space Science Institute).

Other concerns were raised about the freshness of Buratti and Johnson's candidate crater. Solar-wind bombardment causes lunar material to darken and redden over time, but researchers believe such



The bright flare recorded by Leon H. Stuart on November 15, 1953, has defied explanation — but apparently it did not create a fresh pit between the lunar craters Pallas and Schröter.

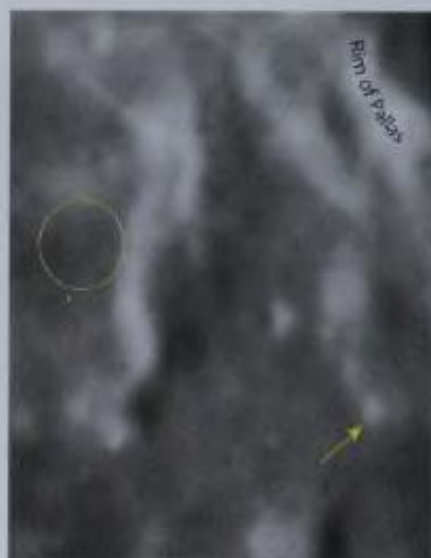
"space weathering" takes place slowly, over millions of years. Thus, if 20-meter-wide objects slam into the Moon often enough to make Stuart's sighting statistically plausible, then the lunar landscape should be peppered with 100,000 bright, fresh-looking splashes — and it isn't. "You can't have it both ways," notes Harris.

Finally, the positional match wasn't as good as Buratti and Johnson first thought. Careful measurement of Stuart's image by *Sky & Telescope* editors Dennis di Cicco and Gary Seronik, as well as by Westfall, shows that the flare was a full 30 km to the northwest of the Clementine candidate crater.

Buratti is reserving judgment until she's had an opportunity to scrutinize Westfall's "prediscovery" images. But a search of Clementine data at the revised position for Stuart's flash shows nothing obvious. "Given the still-existing uncertainties in the position of the flash," Buratti notes, "it looks like there is currently no conclusive candidate for Stuart's flash."

So if it wasn't a flashy impact, what did Leon Stuart see and photograph a half century ago? Some have suggested that it was a "point meteor" headed directly at the camera, but that is ruled out by the flare's duration. Moreover, the spot on the photographic plate is perfectly round, arguing against a stray reflection or emulsion defect. In 1967 Stuart's original underwent a battery of tests at the University of Arizona's Lunar and Planetary Laboratory. But today the whereabouts of the original plate are unknown (May issue, page 10), and without it the mystery of "Stuart's event" may never be solved.

— J. K. B.



Left: An arrow indicates a small, fresh-looking impact feature identified in 1994 Clementine images by Bonnie Buratti and Lane Johnson. Right: The feature also can be seen in this comparison image taken September 13, 1919 (when the Sun was at a less favorable angle), with the 100-inch Hooker reflector on Mount Wilson. Circles show the general location of the flash recorded by Leon Stuart in 1953. Courtesy John Westfall.